4.0 RESEARCH GOALS, QUESTIONS, METHODS AND PROJECT SCOPES

4.1 Introduction to the Research Plan

In 1997, the South Florida Water Management District undertook an Estero Bay and Watershed Management and Improvement Plan, a multi-year project. The District's prime consultant, PBS&J, is charged with conducting an Estero Bay Assessment and an Estero Watershed Assessment. The watershed assessment will develop land and water management strategies to achieve water quality and quantity objectives for the Bay. Major assessment activities include physical descriptions of major features and current management practices, identification of water quality trends, ranking of potential pollution problem areas, and compilation of input data for a watershed model to evaluate management scenarios. A subsequent assessment phase utilizes modeling for scenario evaluation.

The Estero Bay Assessment will define water quality and water quantity objectives or pollution load reduction goals for the Bay and develop tools to evaluate the effects of watershed management techniques on the Bay. The Estero Bay Assessment involves the application of a logical protocol for designing study and management plans, to identify the types of pollutants and their impacts on estuarine environments. The first and present phase of the assessment has resulted in this Estero Bay Research Plan, based on management goals for the estuary. A subsequent assessment phase implements the research plan.

4.2 Estero Bay and Bay Science

Estero Bay is a small estuary on the southwest coast of Florida. Long known to fishermen and nature enthusiasts as a productive and beautiful environment, it otherwise was relatively un-noticed by the general public or state resource managers until after World War II. As the population of Lee County grew, so also did pressures to develop in and near the Bay. Efforts to protect the Bay grew as well, and Estero Bay is distinguished as Florida’s first aquatic preserve. Most of what is known about the Bay is the result of the tension between growth and preservation.

Two periods may be noted as high-water marks for the generation of scientific information on Estero Bay. The first accompanied unsuccessful plans in the early 1970s to develop a large tract of lands fringing the Bay (Estuaries Properties, 1975). The "Estuaries" proposal generated considerable public support for Bay protection. Legal arguments surrounding the proposal eventually led to landmark decisions favoring the State of Florida's authority to regulate development in and near sovereign lands. Studies of the Bay made by the developers and State added much to our present knowledge of the Bay, and in many respects form the earliest or baseline information available on bay ecology.

The second significant period for science in Estero Bay began in the 1990s and has continued through the present. It too has been propelled in large measure by the tension between intense development, and growing public stewardship campaigns. Two features distinguish the present phase. First, more individual studies have been made, or are underway, than in any comparable period of time. Second, investigators are seeking to paint synthetic, comprehensive pictures of the Bay, rather than representing the Bay as a collection of separate, independent facts.

In just the past few years, information on hydrology, water quality, and biology has been collected in common essays about the Bay. These often include information on the Bay's prehistory and history, recreational uses, or future security. The best examples of such syntheses may be found in the "Strategic Plan for Southwest Florida" by the Southwest Florida Regional Planning Council; the "Lee County Comprehensive Plan" and its exhibits and appendices; the "State of the Bay Report" in production by a committee of the Estero Bay Agency on Bay Management, and the annual "Research Studies in Estero Bay Aquatic Preserve," by the Estero Bay Marine Laboratory. A report by W. Dexter Bender and Associates entitled, "Managing the Quality, Quantity, and Timing of Surface Water Discharge into the Estero Bay State Aquatic Preserve" is a succinct synthesis of Bay ecology derived from principles of estuarine science. The "Estero Bay Aquatic Preserve Management Plan" also deserves notice as a 1980s era effort in the same vein.

The present effort, design of an Estero Bay Research Plan, will in subsequent project phases examine what is known of the Bay in considerable detail. In addition to the reports cited above, reports by state and county agencies, unpublished raw data, and other sources of information will be assimilated. A preliminary review of this information has been made for the purposes of A) characterizing dominant features of the Bay, and B) assessing the types and amounts of data generally available to the undertaking. Results are summarized below, for major study subjects.

4.2.1 Geography

Watershed boundaries are better defined than in the past (but see below). The bathymetry of the Bay itself may be out of date, especially near inlets and river mouths. A shoreline survey of the Bay is needed to characterize types and conditions of shorelines, changes through time, and potential future conflicts.

4.2.2 Geology

The geology of Estero Bay has never been studied, except for very recent work by the Estero Bay Marine Laboratory on sediment and core analyses. Possible reasons include the Bay's relative isolation from Charlotte Harbor, comparatively shallow nature, or absence of the federally authorized Intra-Coastal Waterway. In any event, information is lacking on structural geology, sediment dynamics, and other basic aspects. Beach and inlet dynamics have been studied more than Bay geology. The Bay is exceptionally shallow, raising a number of interesting questions. How the bay maintains such shallow depth during the past few centuries of [relatively slow] sea level rise exemplifies such questions. The role of mollusks (oysters and clams) in supplying sediment to the Bay also deserves investigation.

4.2.3 Hydrology

Compared to other Florida estuaries, the watershed is considerably larger than Estero Bay. The Bay may be expected, therefore, to be affected significantly by hydrological changes in the watershed. Subbasin boundaries are better known than previously, but in many places the boundaries are ambiguous, and vary according to water levels. Either because of its natural topography, or because of human-caused changes to drainage, the watershed is susceptible to flooding. Flood studies are numerous, and represent the single most-studied aspect of the Bay and its environs. Oddly, discharge measurements are uneven and records are incomplete. Historic emphasis was placed on stage rather than flow, seriously affecting estimations of nutrient or contaminant loads to the Bay in past years. Flooding in 1995 has kindled new interest in providing flood relief. The District and County are evaluating the feasibility of increasing Estero River discharges, in the context of flow restoration. Several studies are underway as a result.

4.2.4 Hydrography

As mentioned, the Bay is exceptionally shallow. Average tide range exceeds mean bay depth, meaning there is a large potential for tidal action to affect Bay circulation and flushing. Natural tributaries to Estero Bay are short, and small. Their historic flows are largely unknown, but probably were low, and changed gradually in all but the largest storm events, meaning that the eastern side of the Bay was most affected by river discharges. The Rivers have no outlet channels-- the channels end abruptly upon entering Estero Bay, further signifying relatively low discharges. Inlets from the Gulf of Mexico also are small, and dynamic. Inlets have minor channel systems penetrating into the Bay. These circumstances suggest that circulation is different during high tides than low. Circulation characteristics are largely unknown, but under study. The Bay's zones of minimal tidal exchange, or "null zones" are known. Their location, size, and chemistry will be important variables to consider in bay science and management. Finally, given the Bay's shallow nature, wind is probably an important controlling factor over circulation.

4.2.5 Sediments

Bay sediments have been studied, and are being studied, but there is no map of bay sediments as of yet. Most sediment studies have been made in the central and northern reaches of the Bay. Granulometry is known for many stations, although data on the mineralogy of sediments are needed. As mentioned previously, mollusks may play a significant role in the Bay's sediment budget. But we also need to know the extent to which land-based sediments are involved in the bay bottom. There is a strong possibility that Gulf sediments are also a major factor in the Bay's sediment budget.

The thickness of sediments must also be learned. Metals have been studied more than once. Metals originate from uplands and tend to associate with fine particulate matter in the Bay. Metals sometime exceed concentrations normalized to Aluminum, signifying enrichment. Metal "hot-spots" are known in the Bay, and also are thought to disappear after floods.

4.2.6 Fresh Water and Salinity

The Bay is tidally dominated in dry seasons, and salinity is highest. Historic salinity data are available to compare with modern salinity data, at least for central and northern Estero Bay. Salinities tend to be uniform and high throughout the long axis of the Bay. Rivers and major creeks are outlets of fresh water, but their beds are below sea level to US 41 and, in some cases, almost to Interstate 75. This implies that streams are filled with tide water during dry seasons and droughts. Low salinity reaches are compressed into streams. Strong salinity gradients occur along the eastern side of the bay during times of non-zero river flow, but attenuate rapidly. Floods like that of 1995 completely freshen the bay, but not inlets. Hell Peckish Bay is thought to be fresher than expected given its position in the Bay. The bay may be receiving a significant amount of groundwater. Rates of groundwater efflux and its effect on bay salinity are unknown but deserve study.

4.2.7 Water Quality

Estero Bay is designated an Outstanding Florida Water, and classified as Class II and Class III waters of the state. Studies have been spotty but are improving, especially in streams. Water quality baselines exist for Ten Mile Canal, Six Mile Cypress, and the Estero and Imperial Rivers. Some modeling is available to forecast future water quality. Loads of nutrients and contaminants are expected to increase most in the basins yet to be developed fully. Historical bay water quality data are more limited. The middle Bay has been studied the most and the southern Bay, the least. Lee County data indicate that overall water quality in the Bay, since 1991, has been relatively high. The bay is closed to shell fishing, by default for being unclassified. Water quality indices range from fair to good. Hypoxic and anoxic conditions are being reported in shallow water. If supported by additional monitoring, processes responsible for this unusual finding deserve detailed study because low oxygen is unexpected in such a shallow Bay, especially one lacking extensive submerged vegetation.

4.2.8 Ecology

There is considerable disagreement over historic versus modern area of the Bay supporting submerged aquatic vegetation. An early map and the reports of a developer's consultant indicate more SAV than presently occurs. A similar trend is suggested from 2 eras of state SAV mapping in the Bay, and recent work by Lee County, and the Estero Bay Marine Laboratory. On balance, historic agency maps were based on photo-interpretation without ground-truthing, and examination of historic aerial photographs suggests that seagrasses per se may not have been extensive. This is an unsettled issue with significant implications for Bay science and management. Drift macroalgae has recently been cited as a problem. Most non-SAV habitat loss has been via shoreline alteration. On balance, large expanses of native wetlands still fringe the Bay and grow as islands. Bivalves are abundant, but under-studied. Historic data on specific oyster reefs are available. Bivalves may play an important role in regulating water quality and biological processes in so shallow a Bay. The bay harbors manatees and crocodiles (endangered species). Avifauna diversity is particularly high, and CREW (Corkscrew Regional Ecosystem Watershed) contains a number of listed species exceeded by only a few sites in Florida.

4.2.9 Management

Management programs have intimate links to research, for research describes the status and trends of valued resources. Research also gives insight to basic processes affecting resources, and explains how specific stressors exert their [usually undesirable] effects. Actual resource problems facing Estero Bay are poorly documented. Closure of shellfish beds is a definite indicator, as are areas and times when water quality indices are less than good. As documented in the next section, calls for preservation, non-degradation, and restoration are numerous. Laws and policy documents recognize freshwater inflow as a priority item. The bay and tributaries are Outstanding Florida Waters, signifying an intent that no degradation of water quality shall occur. Given that flood control is the biggest land-side issue facing the bay, followed by eutrophication as the biggest water-side issue, maintaining a no-degradation standard will require much new, targeted research. Navigational channels are another emerging water-side issue.

4.2.10 Inferences and Conclusions

Estero Bay is not a data-deficient system, but there exist a number of subjects for which data are insufficient to support analytical assessments of cause and effect, or to support predictions of Bay response to proposed changes, including restoration or mitigation. Likewise, much less seems known of the southern Bay than other reaches.

Except for the SAV issue, most sources feel the bay is not presently impacted, or just beginning to manifest symptoms of decline. In other words, compared to many other bays with active management programs, there are few well-documented problems to fix. Science in Estero Bay will not be driven so much by problem resolution, as by the need to understand basic processes affecting resources of value, which resources are meant to be preserved or enhanced. Research plans recommended for the Bay have therefore sought to meet three objectives-- discover as much as possible of basic processes; be applicable to the management of valued resources, and advance social expectations for the Bay. The following section reviews laws, policies, and programs to identify valued resources and goals for Bay management.

4.3 Part I - Estero Bay Authorities, Valued Ecosystem Components and Goals

The Estero Bay Research Plan followed a method developed by Mote Marine Laboratory for the South Florida Water Management District's study of south Florida estuaries, applied first to the St. Lucie River and estuary. First, goals were established for the Bay. Next, research questions appropriate to each goal were identified. Finally, specific analytical methodologies were defined to implement particular research projects. Taken as a whole, these tasks comprise the Estero Bay Research Plan.

Goals were identified through an analysis of existing laws, rules, policies, and other statements of social expectations for the Bay ("authorities"). These same sources provided insight to the valued ecosystem components of the Bay. Primary goals were developed around each major ecosystem component, and were written to meet criteria of meaningfulness, verifiability, and practicality. Secondary goals were identified around stressors known or suspected to play a significant role in regulating the condition of valued ecosystem components. Where needed, tertiary goals were identified in order to complete a causal link between valued ecosystem components, and management actions.

This section of the Research Plan summarizes a review of authorities made for the purpose of identifying ambitions for, and valued ecosystem components of, Estero Bay. Recommended goals are identified. These goals were used in subsequent tasks to develop empirical questions of two forms: one form sought to establish status and trends of the estuary, and the other form asked questions regarding controlling processes. Such questions then guided the definition of analytical methods which, if implemented in the second phase of the Estero Bay Assessment, are expected to generate information useful in the definition of water quality and water quantity objectives or pollution load reduction goals for the Bay.

On the Nature of Goals in Research

The Research Plan for Estero Bay sought to be goal-driven, which is to say that recommended research will be referable to explicit end-points. Such goals or end-points could be purely scientific, usually meaning that the absence of particular kinds of knowledge is sufficient to justify recommended research. A research plan developed against such standards risks being so broad in scope that it could never be conducted except as a philanthropic or volunteer effort.

The Estero Bay Plan intends that recommended research be basic in nature, i.e., result in new discoveries about the structure and function of the Bay, but that such discoveries also be applicable to contemporary issues of Bay management. Properly crafted, the research plan will identify those particular investigations having, as a whole, a high probability of being useful to resource managers. In order to recommend investigations it was therefore useful to a) understand existing expectations of society relative to Estero Bay, b) identify valued ecosystem components recognized by laws and policies, and c) define research goals that track such resources and expectations as closely as possible, while recognizing the underlying need for basic research.

Good goal statements have three qualities-- they are meaningful, verifiable, and practical. As used here, "meaningful" means that a material improvement to the estuary would follow if the goal was accomplished. "Verifiable" means that an independent observer can determine whether the goal has been met through the use of accepted methods. "Practical" means that the goal does not depend on technology that does not yet exist. A goal does not necessarily have to be legal or affordable to be practical, because legality and economy are changeable social values.

Management goals for estuaries are usually not specific enough to be useful in the design of scientific studies (Estevez, 1991), although this problem has been recognized and efforts have been made to generate better goal statements in other estuaries (Agency on Bay Management, 1990; Kenworthy and Haunert, 1991).

In south Florida, Estevez and Hayward (1992) identified methods by which management goals may be crafted, beginning with a review of:

% General federal and state laws and water quality programs such as the national Clean Water Act and the Florida Water Resources Act;

% Specific management programs at the federal level, such as estuarine and marine sanctuaries, research reserves, wild and scenic river plans, national park management plans, national estuary program plans, et cetera;

% Specific management programs at the state level, such as aquatic preserve plans, outstanding Florida water designations, state park and recreation area management plans, state wild and scenic river plans, et cetera;

% Specific management programs at the regional and local (and private, if appropriate) levels, such as SWIM plans, District surface water programs, local government comprehensive plans, and single mission plans for flood control, mosquito control, soil conservation, et cetera.

Collectively, these "authorities" establish a legal and policy landscape within which existing or prospective information about Estero Bay can be evaluated, for the purpose of establishing research goals. This process anchors the recommended research in the most favorable context for resource management, and was employed for Estero Bay.

A total of twenty-five authorities were consulted in the preparation of research goals for Estero Bay (**Table 1**). Complete analyses of each are given in the Task 1 Report (Estevez, 1998).

Valued Ecosystem Components

Valued ecosystem components of Estero Bay were identified from the authorities, as well as from general estuarine ecology and experiences of other Florida bay management programs. Estero Bay authorities referred to numerous living resources and ecosystem components, captured most thoroughly by the Aquatic Preserve Management Plan. Authorities repeatedly valued ecosystem processes that underlie biotic resources, in particular a natural hydroperiod, and high water quality.

The large palette of valued ecosystem components were simplified somewhat by recognizing primary producers (such as seagrasses and mangroves); lower consumers-- usually benthic fauna (shellfish and other invertebrates, including shrimps and crabs); and higher consumers (fishes, birds, marine mammals), plus natural or historic levels of hydroperiod and water quality.

Despite the ambiguous status and trend of seagrass in Estero Bay, much commended its consideration as a valued ecosystem component. SAV (including rooted macroalgae) is a primary producer, and a unique habitat for many valued species. Many aspects of SAV biology are known, and models exist for their study in new areas. SAV presents attributes (location, area, species composition, depth distribution) amenable to hind-casting as well as forecasting. SAV has been used as a management objective in other Florida bay management programs, with success.

Mangroves were mentioned directly and indirectly by several authorities, and from principles of estuarine ecology deserve such notice. On the other hand, there was a sentiment expressed in these authorities that preservation of existing mangroves, already achieved through a number of regulatory and other programs, is sufficient. But estuarine science strongly suggests that the large area of mangroves in and around the Bay, combined with the Bay's shallow nature, make mangroves an important factor in regulating Bay hydrology, water quality, and biological productivity. Given the inseparable link between mangrove ecosystems and the geology of south Florida, mangroves are likely to figure prominently in the geology of Estero Bay.

Table 1. Laws, rules, programs, plans and reports reviewed for their relevance to research and management in Estero Bay.

Federal

1. Endangered Species Act of 1973
2. Marine Mammal Protection Act of 1972
3. Clean Water Act of 1987
4. Central and Southern Florida Project for Flood Control

Federal - State

5. Big Cypress Basin Issues Characterization Workshop Report
6. Charlotte Harbor National Estuary Program Management Conference Agreement

State

7. Arnold Committee Report and Recommendations
8. Chapter 373 Florida Statutes -- Water Resources Act
9. Chapter 17-40 Florida Administrative Code -- Water Policy
10. Chapter 17-43 Florida Administrative Code -- S.W.I.M. Rule
11. Chapter 403 Florida Statutes -- Environmental Control
12. Chapter 17-302 Florida Administrative Code -- Surface Water Quality
13. Chapter 16-20 Florida Administrative Code -- Aquatic Preserves
14. Estero Bay Aquatic Preserve Management Plan
15. Chapter 17-4 Florida Administrative Code -- Permits

Regional

16. Rules of the South Florida Water Management District
17. Estero Bay and Watershed Management and Improvement Plan Workshop Report
18. Corkscrew Regional Ecosystem Watershed Conceptual Management Plan
19. Identification of Priority Water Bodies within the South Florida Water Management District
20. Strategic Regional Policy Plan of the Southwest Florida Regional Planning Council
21. Draft Principles of the Estero Bay Agency for Bay Management

Local and Private

22. Lee County Comprehensive Plan
23. Lee County Surface Water Management Plan
24. South Lee County Watershed Plan
25. Managing the Quality, Quantity, and Timing of Surface Water Discharge into the Estero Bay State Aquatic Preserve

Lower consumers such as shellfish and crustaceans have ecological, recreational, and commercial value. Oysters, though not approved for consumption in Estero Bay, form reefs that are valuable habitat for many species of fishes. Oysters are sedentary, making them good indicators of water quality. Like SAV, oysters present attributes (location, area, condition, size, depth distribution) amenable to hind-casting as well as forecasting. Oysters have also been used as a management objective in other Florida bay management programs, with success. Shrimps and crabs are harvested for consumption, and are primary prey species for fishes, but the mobility of these animals limits their analytical usefulness as valued ecosystem components. The same limitation applies to higher consumers.

Natural hydroperiods and good water quality have been mentioned as valued ecosystem components. The metrics for these attributes are known. A natural hydroperiod can be calculated through modeling of pre-development conditions. State water quality standards can be used as straight-forward indicators of pollution. Their use in Estero Bay presents some difficulties, however. The topography, water budget, and discharges of the modern watershed are incompletely known. Hind-casting models will face difficult assumptions in the absence of historic data. Water quality criteria do not address nutrients (nitrogen, phosphorus) in empirical terms. Nutrients may not cause ecological imbalance, and this standard must therefore be interpreted using data on living resources such as seagrass. Moreover, there are no standards or criteria for salinity.

These difficulties could be addressed by recognizing oligohaline habitat as a valued ecosystem component. Oligohaline water has a salinity less than 10 parts per thousand (ppt). Seawater has a salinity of about 35 ppt. Oligohaline waters occur in and near sources of freshwater outflow. Their spatial extent and persistence integrate the effects of hydrology and water chemistry. Oligohaline water is amenable to statistical and other types of modeling. As the fulcrum between the land and the Bay, metrics of oligohaline water can serve as "canaries" indicating the net interplay of runoff and tides. Oligohaline water is an essential habitat for the successful completion of many species' life cycle, but sudden or persistent excursions of oligohaline waters into bays harm overall estuarine productivity. Moreover, nutrient enrichment is often expressed as harmful algal blooms or oxygen depletion in low salinity waters, before being expressed in open bay waters. Metrics of oligohaline water could also fulfill the call by authorities for meaningful ecological indicators for the Bay.

Recommended Goals for the Estero Bay Research Plan

A few points must be made as introduction to the research goals for Estero Bay, as these color the form and content of the goals. First among these is the inescapable need for goals to address the widely-held management intent to achieve natural, historic, or pre-development conditions in Estero Bay. No inference is drawn that existing physical changes to the Bay, such as development, are to be undone. Is it possible then, or desirable, to seek natural conditions? For the most part, the answer is yes.

It is highly desirable to seek such a goal from a scientific standpoint. The Bay's present condition largely reflects its original condition, and *presently unknown* conditions of the past are *knowable* through historic records, proxy records, hind-casting, and modeling. Another reason is that the Bay as a system has evolved under a particular combination of physical and chemical conditions, few of which have changed significantly due to the works of humans. When perturbed, the tendency of Estero Bay is toward its structural and functional condition prior to the perturbation. Also, there is little evidence that estuaries "adapt" to profound changes in their structuring influences; they instead persist at sub-optimal levels.

The most compelling point discovered in developing an Estero Bay research plan will no doubt be the least expected among many bay investigators or enthusiasts, and it was this:

> *Geological structures and processes in the bay, watershed, and inshore shelf are [probably] the dominant regulators of Estero Bay's hydrology, water quality, and ecology. Impacts of stressors (altered freshwater inflow, nutrient loadings, contaminants) or trends in valued ecosystem components (seagrasses, fish and wildlife) can be understood and managed only by understanding factors which control the Bay's geomorphology.*

A number of geological factors almost certainly affect most aspects of the Bay's natural processes. Surface water hydrology and water quality are affected by inland topography and soils. Cap stone beneath the Bay may affect groundwater efflux. Seasonal and annual variations in sea level must affect the Bay's circulation profoundly, with cascading effects on water quality, seagrasses and mangroves, and larval recruitment and retention.

Estero Bay's shallow nature is the key to its science and management. Compared to other Florida estuaries, the Bay is very much shallower. Its tidal prism is much greater than tributary inflow under most conditions, yet it has a proportionately larger watershed than other estuaries. The Bay is not merely shallow. It lacks any sign of down-cut channels beyond the mouths of its tributaries, and tidal inlet channels are weak, and short.

As mentioned previously, some disagreement exists regarding the original abundance of seagrasses in the Bay. Yet, the shallow nature of the bay does allow for the possibility that seagrasses a) never were abundant, or b) were abundant but have declined in response to changes in the elevation of the bay bottom. These are speculative interpretations, but other lines of evidence suggest the possibility of depth regulation of seagrasses. In Sarasota Bay, seagrasses do not grow as deeply in areas with higher nutrient loads, than areas with lower loads. Given the large watershed-to-bay ratio in Estero Bay, and as-yet unconfirmed trends of increasing nutrient loading from the watershed, seagrasses may have declined, or be declining, as a result of the Bays' shallow nature.

Most of what has been written of Estero Bay's resources and issues treat the bay's geology as a formless, stable tableau across which flows or nutrient loads have changed, or biological attributes have declined. We need to know how it is that Estero Bay maintains its shallow nature, if such is the case, especially in the face of rising sea level. We need to know where bay sediments originate, how they are transported, and why they are deposited. Are sediments dominated by calcium carbonate, or quartz? Could bivalves in the bay and shallow Gulf be responsible for supplying the bay with sediment? If the sediment originates inland, how has it reached the bay given the rivers' low relief and typically low discharges? What are the implications for circulation, water quality, or biology, of seemingly unimportant channel improvements?

In the research goals that follow, geological foundations of valued ecosystem components were included, to reflect the hypothesized importance to resource management of Estero Bay's geomorphology.

Goals recommended for the development of the Estero Bay Research Plan are given in **Table 2**. Three primary goals were established, for the valued ecosystem components of submerged aquatic vegetation, shellfish, and oligohaline habitats. Each is meaningful in the context of Bay management. Each is verifiable through empirical measurement, and each is practical (achievable with existing technology). Primary goals address primary and secondary producers at the species, community, and habitat levels of biological organization. Each is traceable through intermediate goals to major management issues of freshwater inflow, and water quality.

Restoration of historic conditions for submerged aquatic vegetation creates an opportunity to settle uncertainties that presently accompany trend analyses. Historic conditions may prove to equal or exceed modern conditions, but either outcome will have significant implications for Bay management. It is also possible that some SAV metrics (area, location) have changed while others (species composition, condition) have not, and such distinctions would be essential to discover.

Achieving the primary goal for SAV will require that goals be met for proximate stressors of SAV. Research questions will be needed that address multiple possible sources of turbidity in this shallow Bay. Direct exposure stress also will need investigation. Within the geological setting, structure, and processes affecting the Bay, it will be necessary to learn the extent to which the quantity and quality of freshwater inflows to the Bay regulate proximate stressors.

Improving the shellfish status of Estero Bay requires knowledge of existing shellfish resources, as well as general water quality and surface water sanitation. Research questions can make good use of existing information on oysters, hard clams, and other dominant bivalves. Needed will be data on circulation, water quality, and primary production, all traceable back to freshwater quantity and quality issues. Data on sources, transport, and fates of pathogens also will be needed.

By the same token, the goal of registering oligohaline habitats to their proper landscape position generates a number of research questions regarding freshwater quantity and timing. Taken as a whole, research questions generated for all eight goals should guide the definition of analytical methods which, if implemented in the second phase of the Estero Bay Assessment, may be expected to generate information useful in the definition of water quality and water quantity objectives, or pollution load reduction goals for the Bay.

Future work may seek to relate water quantity, water quality, and pollution load reduction efforts to other valued ecosystem components of importance, especially fish and wildlife. Large, long-lived, and highly mobile species such as birds, or fishes of economic and recreational importance, are regarded as management end-points-- indicators of overall bay health. Unfortunately, the longevity and mobility of these species complicate studies of their dependence upon primary stressors such as water quantity or quality, especially on such small spatial scales as Estero Bay. Few cases are available as models for research where the status of estuarine fishes or birds has been related with statistical significance to primary forces such as freshwater inflow, *per se*. Temperature, salinity, and dissolved oxygen undoubtedly affect the utilization of Estero Bay by fishes, for example, but it is wiser to understand these stressors first, and then use collateral data on habitats, to interpret fish ecology of the Bay.

Table 2. Recommended research goals for Estero Bay.

1.0. Restore the area, location, species composition, and condition of submerged aquatic vegetation (SAV-- sea grasses, rooted macrophytic algae) to pre-development conditions.

1.1. Bring proximate stressors of SAV (light, turbidity, salinity, exposure, biotic regulators, etc.) into ranges suitable for natural recolonization within areas of SAV extirpation.

1.1.1. Modify quantity and quality of freshwater inflows (surface water, ground water) as needed to relieve proximate stressors, within the context of natural geologic conditions in the Bay.

2.0. Create conditions of water quality necessary to increase the area of Estero Bay designated as Class II (shellfish propagation or harvesting) waters of the State, and permit some area of the Bay to be classified "approved" for shellfish consumption.

2.1. Bring proximate stressors of shellfish productivity and sanitation (pathogens, turbidity, salinity, exposure, biotic regulators, etc.) into ranges suitable for shellfish propagation and harvesting.

2.1.1. Modify quantity and quality of freshwater inflows (surface water, ground water) as needed to relieve proximate stressors, within the context of natural geologic conditions in the Bay.

3.0. Register the location, size, and duration of oligohaline habitat (salinity less than 10 parts per thousand) to pre-development conditions.

3.1. Modify quantity and timing of freshwater inflows (surface water, ground water) as needed, within the context of natural geologic conditions in the Bay.

4.4 Part II - Research Questions and Their Rationale

The Estero Bay plan intends that recommended research be basic in nature, i.e., result in new discoveries about the structure and function of the Bay, but that such discoveries also be applicable to contemporary issues of Bay management. The research plan identifies those particular investigations having, as a whole, a high probability of being useful to resource managers. Research questions are heuristic tools that communicate which aspects of Bay structure and function will be investigated, and which will not. The questions allow investigators to infer types of requisite methods and data, and to continually check that methods and data are responsive to research goals. Research questions are not hypotheses. Hypotheses specify an expected and falsifiable outcome of a test, and hypotheses are informed by prior experience and observation. Research questions are more open-ended than hypotheses.

Two Types of Research Questions

Two kinds of questions have been posed. The first kind seeks to learn the status of a given resource, or the spatial and temporal characteristics of a controlling factor. The first kind of question also seeks to determine trends, i.e., whether changes in VEC or controlling factors have occurred through time. The second type of question seeks to learn the nature of causal relationships between VEC and controlling factors, or among controlling factors.

The second task (Estevez and Dixon 1998a) developed research questions unique to each research goal. A total of 58 research questions resulted, of which 37 concerned the status and trends of valued ecosystem components, and 21 concerned controlling causal processes. The 58 questions were combined and distilled to a working number of 19 questions, of which 10 concerned status and trend issues.

Status and Trend Questions (STQ)

STQ. 1. What was the pre-development status of valued ecosystem components, in terms of
- . SAV area, location, depth, species composition, and condition,
- . molluscan shellfish diversity, abundance, and sanitation; and
- c. oligohaline habitat area, location, species composition, and condition?

STQ. 2. What changes in valued ecosystem components have occurred from pre-development to modern time, in terms of
- . SAV area, location, species composition, and condition,
- . molluscan shellfish diversity, abundance, and sanitation; and
- . oligohaline habitat area, location, species composition, and condition?

STQ. 3. What are the geographic and seasonal distributions (and other statistical properties) of measured values for the following stressors regulating valued ecosystem components, *specifically for open Bay waters:*

- water temperature, salinity, light attenuation, color, chlorophyll, mineral and organic turbidity, nutrients, current speed, wave energy, sediment structure and chemistry, and tidal exposure values (for SAV); and
- also pathogen type and abundance, and dissolved oxygen (for shellfish)?

STQ. 4. How have statistical descriptors of present-day stressors changed over the period of available data, for SAV and shellfish in the Bay?

STQ. 5. What are the ranges, statistical distributions, and seasonal and spatial variations of present-day fresh water flow to the Bay, in terms of

- direct precipitation,
- gaged surface water discharge via waterways,
- ungaged surface water discharge via waterways,
- sheet flow,
- water table and surficial aquifers,
- confined aquifers; and
- permitted point and non-point source discharges.

STQ. 6. How have statistical descriptors of present-day fresh water flow changed over the period of available data?

STQ. 7. What are the geographic and seasonal distributions (and other statistical properties) of measured values for the following stressors regulating valued ecosystem components, *specifically for fresh water flowing to the Bay?*

- water temperature, salinity, light attenuation, color, chlorophyll, mineral and organic turbidity, nutrients, current speed, sediment structure, and oxygen demand values (for SAV); and
- also pathogen type and abundance, and dissolved oxygen (for shellfish)?

STQ. 8. How have statistical descriptors of present-day SAV and shellfish stressors changed over the period of available data, in fresh waters flowing to the Bay?

STQ. 9. What are the present-day spatial characteristics of Bay sediments with respect to:

- age, provenance, transport, and deposition,
- thickness, granulometry, and mineral composition,
- organic content and oxygen demand; and
- anthropogenic contaminant concentrations?

STQ. 10. What changes in sediment characteristics have occurred in recent times?

Causal Process Questions

CPQ. 1. What major physical changes have occurred in the study area, in terms of:

- topography of the watershed; and
- bathymetry of the Bay, its tributaries, or Gulf connections?

CPQ.2. What are the present-day seasonal requirements and limits of valued ecosystem components (species diversity, shoot density, biomass, net production, etc. for SAV; diversity, abundance, and sanitation of shellfish; area, location, and species composition of oligohaline habitat), in statistically significant terms of the following stressors:

- freshwater supply and tidal action (for oligohaline habitat),
- water temperature, salinity, light availability, nutrients, current speed, wave energy, sediment structure, and tidal exposure values (for SAV); and
- also pathogen type and abundance, and dissolved oxygen (for shellfish)?

CPQ.3. Is physical recruitment a significant factor limiting SAV or shellfish abundance and production in the Bay? How?

CPQ.4. Do biological interactions regulate valued ecosystem components more than abiotic stressors, specifically in terms of

- epiphytic or drift macroalgal inhibition of SAV; and
- predatory or parasitic inhibition of molluscan shellfish?

CPQ.5. What statistically significant relationships describe the variation of SAV and molluscan shellfish stressors, as functions of the variation in values of freshwater inflow quantity, quality, and timing,

- for stressor values measured in freshwater inflows; and
- for stressor values measured in the Bay?

CPQ.6. What changes in the quantity, quality, or timing of freshwater inflow must be achieved to relieve stressors regulating valued ecosystem components?

CPQ.7. What are the sources, transport mechanisms, and residence times of pathogens in Bay waters and sediments?

CPQ.8. What are the rates of pathogen bioaccumulation and depuration in Bay shellfish?

CPQ.9. Is sea level rise a significant factor affecting valued ecosystem components in the Bay, in terms of

- regulating Bay geometry, elevation, sedimentation, or tidal exposure;
- altering circulation, flushing, or salinity in open waters or tributaries; or
- decreasing maximum depths of submerged aquatic vegetation?

Technical Rationale for Research Questions

Research questions framed the types of investigations needed to complete lines of evidence leading *from* valued ecosystem components *to* management decisions and actions affecting fundamental processes such as freshwater inflow, nutrient enrichment, or contaminant loading. Thus, the underlying rationale for questions posed in this section was that each causes particular kinds of data to be produced in order that status and trends of valued ecosystem components may be defined and linked empirically, if not mechanistically, to their immediate stressors and ultimate regulating factors.

For purposes of this research program, Estero Bay's valued ecosystem components were identified in Chapter 1 as submerged aquatic vegetation, shellfish, and oligohaline habitats. Goals identified in Part 1 posit the management end-points desired for each VEC. Nineteen questions were identified as both necessary and sufficient to establish the status and trends of each VEC, as well as relate the VECs to their respective ecological stressors. Some of the 19 questions also link the status and trends of ecological stressors to the controlling effects of physical, hydrological, and chemical processes.

The total of 19 research questions is recommended as the necessary and sufficient study of Estero Bay, relative to previously adopted research goals. Their distribution by goal is illustrated in **Table 3** and their distribution by VEC, salinity, and water quality is depicted in **Table 4**.

The physical and biological controlling processes to which management actions should be directed can be seen from the technical rationale to fall primarily upon freshwater inflows (for all three VEC), followed by nutrient and pathogen loadings (for SAV and shellfish, respectively). What scope exists for meaningful management actions will depend upon three findings of the recommended research.

First, relationships of VEC to stressors, and of stressors to controlling processes, will define the direction and extent of goal-directed changes that can be expected. Within the range of values used to relate dependent and independent variables, management actions may be expected to cause predictable outcomes. Variable ranges have yet to be analyzed and the strength of their co-variance remains to be tested.

Second, collateral processes such as export of SAV propagules or shellfish predation may be responsible for enduring ecological conditions that limit the scope of VEC response to management actions. Recommended studies will identify the extent of these possibilities.

Third, underlying geological structures, processes, and human alterations may constrain the geographic extent of VEC response to management actions. Knowledge of Estero Bay's geology is central to the design of effective management programs, and recommended investigations will do much to place management options in a useful geological context.

Table 3. Distribution of recommended research questions by goal. STQ, status and trend question; CPQ, causal process question.

Goal Number	Subject	Research Question Number
1.0.	VEC: submerged aquatic vegetation	STQ 1,2 CPQ 2
1.1.	STRESSORS: abiotic and biotic factors	STQ 3,4,7,8 CPQ 2,3,4,5
1.1.1.	CONTROLLING PROCESSES: fresh water, salinity, nutrients, etc.	STQ 5,6,9,10 CPQ 1,2,5,6,9
2.0.	VEC: shellfish	STQ 1,2 CPQ 2
2.1.	STRESSORS: abiotic and biotic factors	STQ 3,4,7,8 CPQ 2,3,4,5,7
2.1.1.	CONTROLLING PROCESSES: fresh water, salinity, pathogens, etc.	STQ 5,6,9,10 CPQ 2,5,6,8,9
3.0.	VEC: oligohaline habitat	STQ 1,2 CPQ 2
3.1.	CONTROLLING PROCESSES: fresh water, salinity	STQ 5,6,9,10 CPQ 1,2,6,8

Table 4. Distribution of recommended research questions by valued ecosystem component (VEC), salinity, and water quality. SAV, submerged aquatic vegetation; S, shellfish; OH, oligohaline habitat.

Research Question	VEC	Fresh Water	Salinity	Water Quality
STQ 1	SAV,S,OH	no	yes	yes
STQ 2	SAV,S,OH	no	yes	yes
STQ 3	none	no	yes	yes
STQ 4	none	no	yes	yes
STQ 5	none	yes	no	no
STQ 6	no	yes	no	no
STQ 7	no	no	yes	yes
STQ 8	no	no	yes	yes
STQ 9	no	no	no	no
STQ 10	no	no	no	no
CPQ 1	no	no	yes	no
CPQ 2	SAV,S,OH	yes	yes	yes
CPQ 3	SAV,S	no	yes	no
CPQ 4	SAV,S	no	no	no
CPQ 5	SAV,S	yes	yes	yes
CPQ 6	SAV,S,OH	yes	yes	yes
CPQ 7	S	yes	no	yes
CPQ 8	S	no	no	yes
CPQ 9	SAV,S,OH	yes	yes	yes

Note: STQ 9 and 10 concern Bay sediments.

4.5 Part III - Research Methods and Their Rationale

This section identifies fundamental research methods applicable to the research questions posed in Part II. A complete description of each method, and a critique for each, are given in Estevez and Dixon (1998b)

On the Nature of Research Methods

Despite the variety of sciences and topics of study typically encountered in estuarine ecology, the methods of inquiry employed in any are often the same. A well-known example might be trend analysis. A geologist may look for changes through time in the sediment structure of an estuarine, whereas a hydrologist or chemist may be interested in patterns of change through time in freshwater inflow, or nutrient concentrations, respectively. Each investigator employs a general method of trend analysis, adapted to the questions and data of their particular science.

Estuarine scientists and managers have a palette of such methods (Table 5) from which to draw in designing and executing basic or applied studies. Experience with these methods in a variety of estuaries reveals merits and weaknesses of each which should be kept in mind when deciding the most appropriate approach to a problem. Some problems require the use of more than one method in order to achieve satisfactory results.

Method selection usually faces three scientific constraints and two practical constraints. Scientific issues include a) the availability of existing data (for some methods), and (for all methods) b) the design and collection of a set of data sufficient for statistical tests of significance, as in the testing of a hypothesis, and c) quality assurance. Methods dependent upon historical data can sometimes be used with "proxy" records that provide hindcasted estimates of requisite parameters. Quality assurance refers to the generation of data that meet pre-determined objectives for precision and accuracy. Projects attend quality assurance through the production and use of standard operating procedures, audits, and other measures. Practical constraints include the logistical difficulty of a project, and its cost. Some logistical requirements (simultaneity, for example) can be extremely difficult to achieve, and budget constraints require difficult choices to be made as a project progresses.

Table 5: Menu of Possible Approaches

APPROACH 1: STATISTICAL REFERENCES

A. STANDARDS
B. TREND ANALYSIS
C. INDEX METHOD
D. TYPICAL VALUE TECHNIQUES
E. NUTRIENT DILUTION

APPROACH 2: ECOSYSTEM COMPONENT ANALYSIS

A. INDICATOR SPECIES
B. VALUED ECOSYSTEM COMPONENT ANALYSIS

APPROACH 3: MODELS

A. NUTRIENT MASS BALANCE MODELS
B. BOX MODELS
C. HYDRODYNAMIC AND WATER QUALITY MODELS

APPROACH 4: EXPERIMENTAL

A. BIOASSAYS AND MESOCOSMS
C. WHOLE-SYSTEM MANIPULATIONS

APPROACH 5: COMPARATIVE

APPROACH 6: GEOGRAPHIC

A. SEGMENTATION
B. SPATIAL ANALYSIS (GIS)

Method Applications to Research Questions

Research questions and methods frame the types of investigations needed to complete lines of evidence leading *from* valued ecosystem components *to* management decisions and actions affecting fundamental processes such as freshwater inflow, nutrient enrichment, or contaminant loading. Thus, the underlying rationale for methods posed in this section has been that each has particular strengths and weaknesses that make it more or less appropriate for research questions posed for Estero Bay.

For purposes of this research program, Estero Bay's valued ecosystem components were identified in Part I as submerged aquatic vegetation, shellfish, and oligohaline habitats. Goals identified in Part I posited the management end-points desired for each VEC. Nineteen questions were identified in Part II 2 as both necessary and sufficient to establish the status and trends of each VEC, as well as relate the VECs to their respective ecological stressors. Some of the 19 questions also linked the status and trends of ecological stressors to the controlling effects of physical, hydrological, and chemical processes. The relationship of methods described in the present chapter, to the research questions, is explored below. Submerged aquatic vegetation is used as an example.

STQ. 1. What was the pre-development status of valued ecosystem components, in terms of... SAV area, location, depth, species composition, and condition?

STQ. 2. What changes in valued ecosystem components have occurred from pre-development to modern time, in terms of... SAV area, location, species composition, and condition?

Trend Analysis is indicated as the method of choice for these questions, augmented with segmentation and GIS tools.

STQ. 3. What are the geographic and seasonal distributions (and other statistical properties) of measured values for the following stressors regulating valued ecosystem components, *specifically for open Bay waters*: water temperature, salinity, light attenuation, color, chlorophyll, mineral and organic turbidity, nutrients, current speed, wave energy, sediment structure, and tidal exposure values (for SAV)...?

STQ. 4. How have statistical descriptors of present-day stressors changed over the period of available data, for SAV...in the Bay?

Trend Analysis should be combined with Standards, Indices, Typical Values and Nutrient Dilution Curves to answer these questions. Mass balance and box models also are appropriate.

STQ. 5. What are the ranges, statistical distributions, and seasonal and spatial variations of present-day fresh water flow to the Bay, in terms of,

- direct precipitation,
- gaged surface water discharge via waterways,

. ungaged surface water discharge via waterways,
. sheet flow,
. water table and surficial aquifers,
. confined aquifers, and
. permitted point and non-point source discharges.

STQ. 6. How have statistical descriptors of present-day fresh water flow changed over the period of available data?

Trend Analysis and Modeling can be performed in geographic segments to address these questions.

STQ. 9. What are the present-day spatial characteristics of Bay sediments with respect to:
. age, provenance, transport, and deposition,
. thickness, granulometry, and mineral composition,
. organic content and oxygen demand, and
. anthropogenic contaminant concentrations?

STQ. 10. What changes in sediment characteristics have occurred in recent times?

Trend Analysis methods augmented with Indices, Typical Values, and Models are indicated.

CPQ. 1. What major physical changes have occurred in the study area, in terms of:
. topography of the watershed, and
. bathymetry of the Bay, its tributaries, or Gulf connections?

Trend Analysis is sufficient to answer this question.

CPQ. 2. What are the present-day seasonal requirements and limits of SAV (species diversity, shoot density, biomass, net production, etc.)... in statistically significant terms of... water temperature, salinity, light availability, nutrients, current speed, wave energy, sediment structure, and tidal exposure values...?

As a causal issue, this question is best answered by using Indicator Species, VEC Analysis, and Bioassay & Mesocosm methods.

CPQ. 3. Is physical recruitment a significant factor limiting SAV...abundance and production in the Bay? How?

CPQ 4. Do biological interactions regulate valued ecosystem components more than abiotic stressors, specifically in terms of epiphytic or drift macroalgal inhibition of SAV...?

CPQ. 9. Is sea level rise a significant factor affecting valued ecosystem components in the Bay, in terms of... decreasing maximum depths of submerged aquatic vegetation?

Mesocosm studies are indicated for CPQ's 3, 4, and 9.

The SAV example illustrates that some methods, such as Trend Analysis, are useful for a number of questions, while other methods such as Mesocosms, are uniquely suited to specific questions. Table 6 illustrates the correspondence of methods to the research questions posed for Estero Bay.

Table 6. Distribution of recommended research methods by question and valued ecosystem component (VEC), salinity, and water quality. SAV, submerged aquatic vegetation; S, shellfish; OH, oligohaline habitat.

Research Question	VEC	Applicable Research Methods from Table 1
STQ 1	SAV,S,OH	1B, 5, 6A
STQ 2	SAV,S,OH	1B, 5, 6A, 6B
STQ 3	none	1A-E, 6A
STQ 4	none	1A-E, 6A, 6B
STQ 5	none	1A-D, 3A, 3B, 6A
STQ 6	no	1A-D, 3A, 3B, 6A, 6B
STQ 7	no	1A-E, 6A
STQ 8	no	1A-E, 6A, 6B
STQ 9	no	1B-D, 2A, 5, 6A
STQ 10	no	1B-D, 2A, 5, 6A, 6B
CPQ 1	no	6A, 6B
CPQ 2	SAV,S,OH	2A, 2B, 4A
CPQ 3	SAV,S	2A, 2B, 4A
CPQ 4	SAV,S	2A, 2B, 4A
CPQ 5	SAV,S	1B-E, 2, 3, 6A
CPQ 6	SAV,S,OH	1-6
CPQ 7	S	2A, 3C
CPQ 8	S	2A
CPQ 9	SAV,S,OH	1A, 2A, 3C, 5, 6B

Note: STQ, status and trend question; CPQ, causal process question.

4.6 Part IV - Recommended Research Projects

In 1997, the South Florida Water Management District undertook an Estero Bay and Watershed Management and Improvement Plan, a multi-year project. The District's prime consultant, Post Buckley Schuh and Jernigan, was charged with conducting an Estero Bay Assessment and an Estero Watershed Assessment. The watershed assessment will develop land and water management strategies to achieve water quality and quantity objectives for the Bay. Major assessment activities include physical descriptions of major features and current management practices, identification of water quality trends, ranking of potential pollution problem areas, and compilation of input data for a watershed model to evaluate management scenarios. A subsequent assessment phase utilizes modeling for scenario evaluation.

The Estero Bay Assessment will define water quality and water quantity objectives or pollution load reduction goals for the Bay and develop tools to evaluate the effects of watershed management techniques on the Bay. The Estero Bay Assessment involves the application of a logical protocol for designing study and management plans, to identify the types of pollutants and their impacts on estuarine environments. The first and present phase of the assessment has resulted in this Estero Bay Research Plan, based on management goals for the estuary. A subsequent assessment phase implements this Estero Bay Research Plan.

Development of the Estero Bay Research Plan entailed the definition of goals, research questions, and methods. Separate reports were developed for each of these tasks (Estevez 1997; Estevez and Dixon 1998a; Estevez and Dixon 1998b), and key elements of each report are given in Parts I, II, and III of this Final Estero Bay Research Plan.

> **Three primary goals** were established, for the valued ecosystem components of submerged aquatic vegetation, shellfish, and oligohaline habitats. Each is meaningful in the context of Bay management. Each is verifiable through empirical measurement, and each is practical (achievable with existing technology). Primary goals address primary and secondary producers at the species, community, and habitat levels of biological organization. Each is traceable through intermediate goals to major management issues of freshwater inflow, and water quality.
>
> **Two kinds of questions** have been posed. The first kind seeks to learn the status of a given resource, or the spatial and temporal characteristics of a controlling factor. The first kind of question also seeks to determine trends, i.e., whether changes in VEC or controlling factors have occurred through time. The second type of question seeks to learn the nature of causal relationships between VEC and controlling factors, or among controlling factors.
>
> **Fourteen different methods** were found pertinent to the questions posed for Estero Bay, and fall into six general approaches: statistical references, ecosystem component analysis; models; experimental approaches; comparative study, and geographic techniques.

The development process culminated in a set of recommended research projects presented below. Each has been crafted so as to support, supplement, or otherwise acknowledge other ongoing or planned research programs in or near Estero Bay, particularly the "Estuary Research Plan for the Upper East Coast and Lower West Coast," prepared by the South Florida Water Management District and Florida Center for Environmental Studies, and the "Compendium of Current Monitoring Programs in Charlotte Harbor and Complex Watersheds," prepared for the Charlotte Harbor National Estuary Program. Annual reports beginning in 1996, of the Estero Bay Marine Laboratory, have also been consulted for guidance.

Eight research projects have been designed. Most are comprised of separate but related tasks --a total of 22 tasks are presented. Research projects address VEC status and trends, VEC stressors, and causal processes linking VEC to stressors. Titles of the projects include:

-- SAV History and Trend Analysis
-- Molluscan Shellfish History and Trend Analysis
-- Oligohaline Habitat History and Trend Analysis
-- History and Trend Analysis for VEC Stressors
-- Ecological Studies of SAV Production and Regulation
-- Ecological Studies of Shellfish Production, Regulation, and Sanitation
-- Sedimentology
-- Bay Water Quality Model

To the extent possible, each project follows a similar format, and some projects have been divided into project elements or have been supplemented with collateral investigations. A logical order for scheduling projects is given, and opportunities to link projects logistically are identified. Schedules recommended for these research projects are not intended to imply more than the optimal transfer of findings from one study to the next. No projects are compared in terms of scientific rank or merit-- all are considered necessary and sufficient to produce new, basic insights to Estero Bay that are directly applicable to the Bay's management needs.

Project scopes of work may be thought of as the technical elements for "Requests for Technical Proposals" available to the South Florida Water Management District, Estero Bay Agency on Bay Management, Southwest Florida Regional Planning Council, Charlotte Harbor National Estuary Program, or other agency to employ in furtherance of the Estero Bay and Watershed Management and Improvement Plan. Applicants for funding should be expected to submit technical proposals rather than statements of qualifications, in order to take full advantage of different scientific approaches to each research project, and to provide reviewers with additional selection criteria, such as familiarity with Estero Bay.

On Bay Segmentation and Hydrodynamic Models

Segmentation, or the geographic partitioning of a study area, is a useful tool in the design of research and monitoring programs. Segmentation recognizes variations and gradients that occur naturally in a coastal landscape. It simplifies and makes explicit assumptions about stratification in the design of statistical analyses, and allows for the equitable distribution of effort to be tested among and between segments. The process also allows for some geographic areas to receive unique monitoring or research efforts.

Segmentation relies heavily on existing information to match bay regions to monitoring and research effort, although it is possible to conduct scoping studies or reconnaissance surveys upon which a preliminary segmentation system can be based. Elements of surveys made for such purposes depend largely on the questions upon which new monitoring or research will be based: a detailed study of sediment contaminants, for example, would seek to map Bay depths, granulometry, and circulation patterns as input to a segmentation scheme, but data on living resources might not be initially as important.

Considerable data exist for the Estero Bay area. Data of the types and kinds needed for segmentation are fewer because historic effort has not been uniformly dispersed across the Bay; changes in historic conditions are believed to have occurred, but are not completely documented as yet, and even the boundaries of Estero Bay's watershed are changing as new data are analyzed.

Using depth and current data, Estero Bay Marine Laboratory divided Estero Bay into 12 hydrographic zones, and then consolidated these into 4 major zones or segments. This Estero Bay Research Plan intended to adopt the EBML zones as provisional or working segments for new Bay studies, and recommends the 4 major segments to prospective investigators.

However, the South Florida Water Management District has engaged the University of Florida to develop a three-dimensional, curvilinear hydrodynamic and salinity model for lower Charlotte Harbor, including Estero Bay. In light of this development, segmentation of Estero Bay beyond that developed by EBML should be deferred until products of the hydrodynamic model are available. The model will employ updated data on bay geometry such as bay shorelines, and bathymetry. The model will simulate freshwater inflows, tides, and winds to describe patterns of circulation, flushing, and salinity in the Bay under a variety of meteorological, hydrological, and oceanic conditions.

Elements of the Estero Bay Research Plan begun immediately should employ the EBML segmentation system as needed. Because the bay model will identify the natural and synoptic physicochemical structure of the Bay, it should eventually be used for segmentation, as well as the basis for decisions on the geographic locations for field sampling and measurement in elements of the Estero Bay Research Plan that begin after 2002.

Uses and outputs of the hydrodynamic and circulation model supportive of research projects described below may be summarized as follows. First, a second set of model input files should be created to represent historical conditions. By this recommendation, the geometry of the Bay would be naturalized to remove filled shorelines and dredged channels. Inlets would be configured to an historic condition. Fresh water inflows would simulate runoff from undeveloped watersheds. Second, for both modern and historical (hindcast) conditions, a relatively long period of time would be simulated --at least a year. Output data for salinity and other water quality parameters would be compiled so as to allow isopleth maps of the bay to be drawn. Maps will be depict mean conditions, variations, and tidally filtered results. Third, spatial analyses seek matches between mapped model outputs and resource maps developed for the Bay. Fourth, changes in the Bay's physico-chemical conditions (historic vs. modern) are depicted and matches are sought between these changes and changes established for resources as part of the trend analyses in the EBRP. Fifth, the model can be employed to determine what changes to flows, timing, or quality would restore VEC to target levels.

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4.7 The Estero Bay Research Plan - Acronyms, Definitions, and Notes

Class II Waters: In Estero Bay, "Matanzas Pass, Hurricane Bay, and Hell Peckish (Peckney) Bay- from San Carlos Bay to a line from Estero Island through the southernmost tip of the unnamed island south of Julies Island, northeastward to the southernmost point of land in section 27 T46S R4E." (FDEP 1996 State Water Quality Standards, S.62-302 FAC)

Cultch: Shells of recently-alive oysters deployed as a physical substratum for new oyster colonization.

Data Management: recommended program, procedures and documentation to ensure that data and meta-data requirements of sponsoring agencies are met.

Duration: time in months required to conduct a study.

EBRP: Estero Bay Research Plan

Estero Bay: unless otherwise noted, protected tidal waters from San Carlos Bay south to Wiggins Pass, east of a chain of barrier islands and including the waters of tidal inlets.

Executable With Project(s): other projects named in the EBRP that can be performed jointly with the present project.

GIS: Geographic information system-- computer based system for creating and analyzing spatial information such as map elements; also query engine for analysis of spatial relationships.

GPS: Global positioning system-- satellite based system of signals supporting mobile instruments that allow for the latitude and longitude of a place to be determined with known precision.

Leads From Project(s): other projects named in the EBRP that should be performed before the present project.

Leads To Project(s): other projects named in the EBRP that should follow the present project.

Quality Assurance: recommended program, procedures and documentation to ensure that data quality objectives for precision, accuracy, and completeness are met; also corrective actions.

Pre-Development Condition: Conditions *found through the proposed research* to have existed for valued ecosystem components prior to changes attributable to recent human settlement and development. Because little is presently known of Estero Bay's ecological past, pre-development conditions must be discovered rather than defined *a priori*.

References: citations of literature on studies in Estero Bay, or elsewhere, relevant to the proposed study.

SAV: Submerged aquatic vegetation.

Scope of Work: a description of types and extent of technical study envisioned for the study; guidance for proposals in which additional details, alternatives, or other changes are proffered.

Task: an element of work within a study plan separable from other work by technical content or logistical requirements.

Tributaries: unless otherwise noted, Cow, Hendry, Mud, and Spring creeks, Ten-Mile Canal, and the Estero and Imperial rivers.

VEC: Valued ecosystem components, in the EBRP, seagrasses, shellfish, and oligohaline habitats.

Water Quality Criteria: Numerical standards established by the State of Florida for water of various classification. Class II and Class III criteria may be viewed at the FDEP site on the worldwide web, *http://www2.dep.state.fl.us/water/division/standards/302tbl.pdf*

4.8 The Estero Bay Research Plan

4.8.1 SAV History and Trend Analysis

Project Title: SAV History and Trend Analysis

Valued Ecosystem Component: Submerged Aquatic Vegetation

Major Goal: Restore the area, location, species composition, and condition of submerged aquatic vegetation (SAV-- sea grasses, rooted macrophytic algae) to pre-development conditions.

Question(s): What was the pre-development status of SAV area, location, species composition, and condition? What changes have occurred from pre-development to modern time, in terms of these attributes?

Duration: 18-24 months.

Leads From Project(s): No antecedent.

Leads To Project(s): History and Trend Analysis of VEC Stressors

Executable With Project(s): Molluscan Shellfish History and Trend Analysis

<u>Scope of Work</u>

Background: Estero Bay is a shallow estuarine environment with water depths generally less than those associated with deep edges of SAV beds in other west Florida estuaries. Seagrasses and rhizophytic macroalgae presently occur in Estero Bay but their status relative to historical or pre-settlement conditions is uncertain. Past mapping efforts have relied on aerial photographs taken at different times of the year, or variable conditions of visibility. Some mapping efforts employed little or no ground truthing, probably resulting in dark mud or algae being mapped as seagrass. Management of Estero Bay would benefit from a more definite understanding of its SAV history in terms of SAV area, location, species composition, and condition, but attempts to make such determinations in other estuaries have met with limited success. Often, it has been possible only to reconstruct the locations and areas of seagrass beds. Sources of historical information on species composition are fewer, and condition hind-casts are rare or based on anecdotal information.
Investigations are sought to determine as much as possible concerning the historical and present-day status and trends of SAV in Estero Bay. Four tasks are defined in two project phases, with Phase 2 work depending on the results of Phase 1 findings. Phase 1 entails an analysis of historical and modern imagery (maps, charts, and aerial photographs), and a change analysis performed in a geographical information system (GIS). Phase 2 entails the use of relict mollusk shells to reconstruct the locations of historical SAV beds.

Task 1. Historical image analysis. As part of a Phase 1 study, a diligent effort will be made to inventory and evaluate all historical maps, navigation charts, and aerial photographs of Estero Bay. Prospective sources include the U.S. Army Corps of Engineers, U.S. Geological Survey, U.S. Coast and Geodetic Service, National Oceanic and Atmospheric Administration, Library of Congress, Florida Bureau of Geology, Florida State Museum, Florida Marine Research Institute, and archival collections of universities, local governments, and the Estero Bay Marine Laboratory. Other sources will be identified and investigated. Meta-data files will be created for each set of imagery so located, including source, type, scale, coverage, date, and, if recorded, time of day or tidal stage. To the extent possible according to the quantity and quality of information found, multiple sources of data will be used to create composite maps of certain and potential SAV at decadal intervals. Bathymetric information will be compiled in a similar manner. Maps will distinguish areas of the Bay according to SAV cover and persistence, as in "always present", "intermittently present", or "possibly present": other systems may be employed.

Task 2. Modern aerial photographs and ground-truthing. As part of a Phase 1 study, new aerial photographs will be ground-truthed to produce a map of present day SAV in Estero Bay. Aerial photographs from any ongoing or planned agency study of the Bay may be employed if criteria listed below are met, or new photographs may be taken. New studies will be informed by previous work by Fite and Kibbey (1992), Sargent et al. (1995), and Estero Bay Marine Laboratory. Useful photographs will be vertical, true-color, taken in spring or early summer at low tide under zero cloud cover and negligible haze, during a period of time when freshwater inflows from Bay tributaries are not so great as to obscure bottom visibility. Photographs will be printed in large format at a scale of one inch to 200 ft. (preferred) or 400 ft. (acceptable). Photographs will be used to ground-truth all SAV signatures. Ground-truthing shall determine the dominant species of SAV in each signature, other species (especially drift macroalgae), and cover. Cover shall be determined using the Braun-Blanquet technique. Differential GPS (global positioning systems) will be used to define boundaries of each SAV bed so delineated.

Task 3. GIS change analysis. As part of Phase 1 study, decadal history maps of SAV from Task 1, and present day SAV maps from Task 2, will be compiled and compared using GIS. For consistency, criteria and standards for GIS work will be provided by the sponsoring agency. Separate maps will be produced for each antecedent decade (or other intervals justified by research) and for modern conditions. Scales, codes, labels, and other conventions will be uniform among all such maps. Analysis required of these maps shall be for step-wise and overall changes in SAV location, area, and if possible, species composition and condition (cover). A summary map will depict major patterns and trends in SAV within Estero Bay. Analysis recommended for the same data includes comparison of SAV dispersion to bathymetric features of the Bay. Information on present day bathymetry will be obtained from, or agree with, bathymetric data employed by the University of Florida's hydrodynamic model of Estero Bay. SAV change data will be analyzed to determine the effects of bathymetric changes in the Bay.

Task 4. Molluscan indicators. A second and more exploratory phase of the study will be undertaken if warranted by the results of Phase 1. Task 4 will determine the extent to which historical SAV beds can be inferred from the sedimentary record, based on the presence of relict mollusk shells. In Florida Bay, work by the U.S. Geological Survey (Reston, Virginia) has found regular associations of certain mollusk species and turtle grass (*Thalassia testudinum*), as well as associations of other species with macro-algal mats. In this study, present-day mollusk communities associated with vegetated and unvegetated bottoms in Estero Bay will be catalogued, with an emphasis placed on epifaunal species of mollusks. Similar work may be proposed for adjacent or similar inshore waters, such as Tarpon Bay, in order that multiple species of SAV can be studied. Affinities of particular species with bottom type or SAV species will be evaluated through statistical analysis. Cores will be taken at specific sites suggested from Phase 1 study. These sites will be places where evidence points to the prior occurrence of SAV beds. Cores will be stratified, dated using appropriate techniques, and studied for the presence of SAV-indicator species during the previous 100 years. This information will be used to amend or enhance GIS products described in Task 3.

Quality Assurance: See Appendix 1

Data Management: See Appendix 2

References:

Brewster-Wingard, G.L., S.E. Ishman and T.M. Cronin. Historical salinity and seagrass trends in Florida Bay derived from benthic faunal data. http://www.aoml.noaa.gov/flbay/brewsteretal.html.

Fite, S.D. and K.A. Kibbey. 1992. Assessment of seagrasses in Estero Bay Aquatic Preserve. Lee County Environmental Laboratory, 103 pp.

Sargent, F.J., T.J. Leary, D.W. Crewz and C.R. Kruer. 1995. Scarring of Florida's seagrasses: assessment and management options. FMRI Technical Report No. TR-1. 43 pp.

4.8.2 Molluscan History and Trend Analysis

Project Title: Molluscan History and Trend Analysis

Valued Ecosystem Component: Molluscan Shellfish

Major Goal: Create conditions of water quality necessary to increase the area of Estero Bay designated as Class II (shellfish propagation or harvesting) waters of the State, and permit some area of the Bay to be classified "approved" for shellfish consumption.

Question(s): What was the pre-development status of molluscan shellfish diversity, abundance, and sanitation? What changes have occurred from pre-development to modern time, in terms of these attributes?

Duration: 18-24 months.

Leads From Project(s): No antecedent.

Leads To Project(s): History and Trend Analysis of VEC Stressors

Executable With Project(s): SAV History and Trend Analysis

Scope of Work

Background: Estero Bay is a shallow estuarine environment across which salinity gradients from freshwater to seawater have existed over short land-sea distances. Such gradient compression, coupled with the shallow sub-surface presence of capstone, create favorable conditions for the colonization and growth of oyster reefs in certain areas. Other areas are more likely to support gastropods and bivalves with more marine affinities. Oysters reefs and beds of infaunal bivalves represent important ecological communities in Estero Bay, and where water quality is adequate, the shellfish also represent a commercial and recreational resource of value. Historical information and the history of shellfish regulation suggest that Estero Bay once supported more harvestable shellfish than at present. In order to know the potential for restoring or maintaining shellfish populations, and shellfish sanitation, it is necessary to know more of shellfish history and ecology in Estero Bay. Management of Estero Bay would benefit from a more definite understanding of its shellfish history in terms of mollusk bed areas, locations, species composition, and condition. Determining the historic and modern distributions of oyster reef is a straightforward task, as is the study of infaunal mollusk species. Paleoecological methods exist to assess shellfish condition, but there are presently no methods for hind-casting shellfish sanitation.

Investigations are sought to determine as much as possible concerning the historical and present-day status and trends of shellfish in Estero Bay. As used here, shellfish refers to gastropods and bivalves of interest, and excludes crabs, shrimps, and other crustaceans. Four tasks are defined. Tasks 1-3 concern oyster reefs and entail an analysis of historical and modern imagery (maps, charts, and aerial photographs), and a change analysis performed in a geographical information system (GIS). Tasks 1-3 are similar to and may be done as part of SAV History and Trend Analysis, Phase 1. Task 4 is a reconnaissance effort concerning historical and present day distributions of macro-infaunal mollusks, and may be coordinated with Phase 2 of SAV History and Trend Analysis, performed as part of the Geological History and Sediment Budget project, or both.

Task 1. Historical image analysis. As part of a Phase 1 study, a diligent effort will be made to inventory and evaluate all historical maps, navigation charts, and aerial photographs of Estero Bay. Prospective sources include the U.S. Army Corps of Engineers, U.S. Geological Survey, U.S. Coast and Geodetic Service, National Oceanic and Atmospheric Administration, Library of Congress, Florida Bureau of Geology, Florida State Museum, and archival collections of universities and local governments. Other sources will be identified and investigated, especially U.S. Coast & Geodetic Survey Topographic Map 5860 Series, Florida Gulf Coast (scale 1:10,000) produced from 1939-1943 data. Meta-data files will be created for each set of imagery so located, including source, type, scale, coverage, date, and, if recorded, time of day or tidal stage. To the extent possible according to the quantity and quality of information found, multiple sources of data will be used to create composite maps of certain and potential oyster reefs at decadal intervals. Bathymetric information will be compiled in a similar manner.

Task 2. Modern aerial photographs and ground-truthing. As part of a Phase 1 study, new aerial photographs will be ground-truthed to produce a map of present day oyster reefs in Estero Bay. Aerial photographs from any ongoing or planned agency study of the Bay may be employed if criteria listed below are met, or new photographs may be taken. Useful photographs will be vertical, true-color, taken in spring or early summer at low tide under zero cloud cover and negligible haze, during a period of time when freshwater inflows from Bay tributaries are not so great as to obscure bottom visibility. Photographs will be printed in large format at a scale of one inch to 200 ft. (preferred) or 400 ft. (acceptable). Photographs will be used to ground-truth all oyster reef signatures. Ground-truthing shall determine the elevation (awash or submerged at low water) of each reef, condition (density; percent living; size; meat weight and total weight; presence of predators, parasites, diseases), and other common species. Differential GPS (global positioning systems) will be used to define boundaries of each oyster reef so delineated.

Task 3. GIS change analysis. As part of Phase 1 study, decadal history maps of oyster reefs from Task 1, and present day oyster reef maps from Task 2, will be compiled and compared using GIS. For consistency, criteria and standards for GIS work will be provided by the sponsoring agency. Separate maps will be produced for each antecedent decade (or other intervals justified by research) and for modern conditions. Scales, codes, labels, and other conventions will be uniform among all such maps. Analysis required of these maps shall be for step-wise and overall changes in reef location, area, and condition. A summary map will depict major patterns and trends in oyster reefs within Estero Bay.

Task 4. Molluscan indicators. A fourth and more exploratory task of the study addresses infaunal mollusks, which are cryptic and not detectable from the surface. Task 4 will seek to determine the location, size, and species composition of dominant, extant shellfish beds, if any, in Estero Bay. A reconnaissance will be made of the Bay to determine suitable locations for east-west transects extending from the mainland shore to the barrier islands. Transects will be spaced at approximate intervals of 0.5 km. Other north-south transects, and spot-locations, may be established as needed to provide adequate effort on major tidal flat systems in the Bay. At multiple stations along each transect, and at spot-locations, position will be determined by GPS. At each station or spot-location, a single major quadrat (10m by 10m) will be examined for siphons, mounds, dead shells, and living animals burrowed into the sediment. Any major quadrat with living specimens of target species will be sub-sampled with 5 randomly deployed 1m by 1m quadrats, to determine animal densities by species. Target species will include but may not be limited to the hard clam (Mercenaria campechiensis et var.), sun ray venus (Macrocallista nimbosa), pen shell (Atrina rigida), surf clam (Spisula solidissima arveneli), carolina marsh clam (Polymesoda carioliniana), common rangia, (Rangia cuneata), and bay scallop (Argopecten irradians). Contiguous areas of living bivalve communities will be delineated on GIS maps. Based on their distribution and character, additional effort will be made to identify relict (dead) assemblages of bivalves in other areas of the Bay. Sediment at prospective sites will be probed with a steel bar. Evidence of buried shell will sought in test pits excavated from the Bay bottom. Emphasis will be placed on locating recent assemblages of animals preserved in life-positions rather than older assemblages of weathered or re-worked shell deposits. Results will be used to produce maps and reports comparing modern to historic shellfish communities.

Quality Assurance: See Appendix 1

Data Management: See Appendix 2

References:

Tabb, D.C., R.G. Rehrer, P. Larsen, S. Berkeley, E.J. Heald, M.A. Roessler and T.A. Alexander. 1974. Ecological inventory of coastal waters and adjacent uplands of Lee County, Florida in the vicinity of the Estero Bay Marine Preserve. UM_RSMAS Report No. 75013.

4.8.3 Oligohaline Habitat History and Trend Analysis

Project Title: Oligohaline Habitat History and Trend Analysis

Valued Ecosystem Component: Oligohaline habitat

Major Goal: Register the location, size, and duration of oligohaline habitat (salinity less than 10 parts per thousand) to pre-development conditions.

Question(s): What was the pre-development status of oligohaline habitat in terms of area, location, species composition, and condition? What changes in oligohaline habitat have occurred from pre-development to modern time, in terms of these attributes?

Duration: 12 months

Leads From Project(s): Hydrodynamic model of Estero Bay by University of Florida for South Florida Water Management District (external to Estero Bay Research Plan).

Leads To Project(s): None

Executable With Project(s): None

Scope of Work

Background: Oligohaline water (salinity of less than 10 parts per thousand, or "ppt") occurs in upper estuarine areas near freshwater inflows. At very low salinities (<0.5 ppt) waters are described as tidal fresh. Based on incomplete data, most large tributaries to Estero Bay contain small reaches of tidal fresh water, with reaches as far upstream (east) as approximately U.S. Highway 41. Reductions in tributary flow cannot force tidal fresh waters further east, but oligohaline water can move up each tributary and compress the area of tidal fresh water. Increases in tributary flow can create tidal fresh conditions throughout the length of each stream, and force oligohaline salinities to cover wide expanses of Estero Bay. Prolonged reductions in salinity harm estuarine resources, especially when the rates of change are faster than naturally occurred. Historical data suggest that natural freshwater inflows generally were low, and changed gradually, signifying that oligohaline waters were stable but small areas of the overall Bay, limited to tributaries and their immediate proximity. But improvements to tidal inlets, sea level rise, and increased tributary discharges now work to expand oligohaline areas of the Bay during wet periods, and accelerate oscillations from marine to freshwater conditions, through time. A hydrodynamic and salinity model presently under development for Estero Bay has the ability to compare historic tidal and inflow conditions to modern conditions, in order to assess the spatial and temporal changes that have occurred to oligohaline habitat. This project investigates present day evidence for the spatial extent of oligohaline waters in the Bay, and changes to living resources in, and affected by, oligohaline waters.

Task 1. Stream bed elevations. Surveys are needed to relate the elevation of stream beds to tidal datum planes, especially higher high waters, for their intersections define the inland most boundary of tidal fresh or oligohaline conditions. Natural and artificial sills may also regulate inland movements of saline water and will be identified. This task provides for surveys across or along the lengths of Hendry, Mullock and Spring Creeks, Ten-Mile Canal, and the Estero and Imperial Rivers, where existing surveys do not exist or are found to be inadequate. Elevations will be measured relative to the National Geodetic Vertical Datum (NGVD) rather than the North American Vertical

Datum. Tidal datum planes will be adjusted relative to NGVD and corrections to tidal planes will be made for sea level rise since the last determinations. Local surveys will characterize sills, holes, dredged channels, or other bathymetric features of interest. Existing conditions will be compared to historical data for change analysis and hydrodynamic models that hindcast natural inflow and circulation conditions.

Task 2. Mapping of low salinity biological indicators. This task seeks to determine the maximum geographic extent of present day oligohaline habitats of Estero Bay. A list of species shall be developed, including representatives of algae, submerged and riparian vascular plants, invertebrates, and fishes known from other studies in south Florida waters as biological indicators of oligohaline habitats. Rapid survey techniques will be defined and applied within each tributary from its mouth to the stream bed intercepts of mean higher high water (from Task 1), or controlling structure. The same techniques will be employed at regular intervals between tributaries along the mainland shore of Estero Bay and extend into the Bay as deemed necessary by local conditions. Surveys will be performed twice, once during a dry season and once during a wet season provided the previous calendar year has been free of hydrological extremes (droughts or floods).

Task 3. Historical extent of oligohaline habitats. Physical disruption to most Bay tributaries precludes their study by methods of historical or paleoecology, but open Bay bottoms are largely undisturbed. Task 3 will determine the extent to which historical areas of low salinity can be inferred from the presence of indicator species preserved in the sedimentary record. Cores will be taken at specific sites along the eastern Bay shore suggested from Task 2 study. Cores will be stratified, strata will be characterized as to granulometry and mineralogy, dated using appropriate techniques, and studied for the presence of oligohaline habitat indicator species during the previous 100 years. Examples of indicator species include representatives of angiosperms (as pollen), foraminifers, diatoms, ostracodes, and mollusks. Data will be analyzed to determine whether modern oligohaline areas are expanding into open Bay waters.

Quality Assurance: See Appendix 1

Data Management: See Appendix 2

References:

Brewster-Wingard, G.L., S.E. Ishman and T.M. Cronin. Historical salinity and seagrass trends in Florida Bay derived from benthic faunal data. http://www.aoml.noaa.gov/flbay/brewsteretal.html.

4.8.4 History and Trend Analysis for VEC Stressors

Project Title: History and Trend Analysis for VEC Stressors

Valued Ecosystem Component: Submerged aquatic vegetation and molluscan shellfish

Major Goal(s): Restore the area, location, species composition, and condition of submerged aquatic vegetation (SAV-- sea grasses, rooted macrophytic algae) to pre-development conditions; Create conditions of water quality necessary to increase the area of Estero Bay designated as Class II (shellfish propagation or harvesting) waters of the State (*see* Definitions), and permit some area of the Bay to be classified "approved" for shellfish consumption.

Question(s): What are the geographic and seasonal distributions (and other statistical properties) of values for the principal stressors of SAV and shellfish, as measured in the Bay and its tidal tributaries? How have statistical descriptors of present-day stressors changed over the period of available data, in the Bay and tidal tributaries?

Duration: 24-36 months.

Leads From Project(s): History and Trend Analysis of SAV and Molluscs

Leads To Project(s): Ecological Studies of SAV and Shellfish Production

Executable With Project(s): Ecological Studies of SAV and Shellfish Production

<u>Scope of Work</u>

Background: Several productive and meaningful studies have been made of water quality in Estero Bay. New data are needed to fill gaps in existing data, provide data on unstudied areas and parameters, and support collateral studies. It is necessary to increase the spatial density and temporal frequency of measurements made in monitoring, for example. Considerable insight to Estero Bay's environmental status can be achieved through synoptic, simultaneous program of sampling and measurement. Proposed studies resemble a monitoring program and data from the proposed studies will be useful as new monitoring is undertaken. However, the proposed studies are not intended to continue for longer than approximately 24 months. Each will result in new insight to spatial gradients of water quality across the bay; short-term changes in water quality through time, and characteristics of places and parameters of special interest. Sampling will provide simultaneous and continuous data for certain parameters in streams and each bay segment. Additional parameters will be sampled less frequently but at higher spatial density, and these data will be analyzed with dilution curves. The chemistry of null zones will be investigated to assess their role in bay ecology, and potential use as sentinel sites. All of these data will inform collateral studies of seagrasses, mollusks, and oligohaline habitats and many data will be relevant for studies of shellfish sanitation. It will be necessary, however, for a major new undertaking insofar as shellfish sanitation is concerned. Existing data on shellfish sanitation must be improved through the addition of pathogen studies in shellfish, water, and sediment; increased spatial and temporal effort, and the study of a much larger set of potential pathogens.

Task 1. Continuous monitoring. This task provides for the continuous in-situ monitoring of certain water quality parameters in tributaries and segments of Estero Bay. Six tributary stations will be occupied with two stations in each of the major tributaries (Ten Mile Canal group; Estero and Imperial Rivers). One station in the tributaries will be near their entry to the Bay. The second station in major streams will be located at or downstream of the gaging station where stream discharge is measured (see monitoring recommendations of the Watershed Study). Another set of stations will be centrally located in each of the Bay's four major segments, as defined by Estero Bay Marine Laboratory (1998). One station will be situated within a null zones between bay segments (for example, near Julies Island), and one station will be deployed in open waters of the Gulf of Mexico. A total of 12 stations will be outfitted with continuous recorders of water quality measured in-situ. All instruments will be deployed off the bottom and will be submerged during low tides. Instruments will measure and record water temperature, pH, conductivity, and dissolved oxygen on 60 minute intervals. Four of the stations (tributary, tributary mouth, bay segment or null zone, Gulf of Mexico) will also be outfitted with continuous recorders of in-situ light climate. Such instruments will have multiple sensors in order to allow for the computation of extinction coefficients. This task shall not be undertaken until discharge gages are deployed in tributaries and a source of local tide measurements is available. In the absence of a tide gage, one or more water level recorders may be operated for the duration of the survey. At least one full water year of data should be collected at all stations, allowing as needed for data gaps caused by servicing, replacements, calibrations, and other maintenance duties.

Task 2. Baywide synoptic water chemistry. This task provides for a spatially intense program of sampling and measurement, at only three periods of time. Trips will be triggered by hydrological conditions so as to capture a spring dry season, a summer-fall wet season, and a fall-winter dry season. The timing of trips within a season will be determined by tides, allowing for a daytime high tide and a daytime low tide to be sampled in succession. Station locations will be governed by accessibility but generally there will be one station in each of 10 bay sub-segments defined by Estero Bay Marine Laboratory (1998), two stations in the Bay's three major tributaries, one station in each minor stream, one station in the null zone study area, and at least one station in the Gulf of Mexico. This total of approximately 24 stations will be visited synoptically at slack high and slack low tides. Special arrangements may be required to reach shallow bay segments at low tide. At each station and visit, surface and bottom measurements will be made of water temperature, specific conductance, pH, salinity, dissolved oxygen, and photon flux (light intensity). A mid-depth sample will be collected and returned from each station and visit, and analyzed for color, chlorophyll a, total suspended solids, mineral and organic turbidity, nutrients (N and P), biochemical oxygen demand,

and coliforms (total, fecal, fecal strep). Nutrients will include nitrate plus nitrite, ammonia, total kjeldahl, and total nitrogen forms, plus orthophosphorus and total phosphorus. Water depth and secchi disk depth will be recorded once per station visit.

Task 3. Water Quality Change Analysis. This task provides for the compilation, screening, and comparison of historical water quality data to data collected in Tasks 1 and 2. Few historical data will be directly comparable to data from Tasks 1 and 2. It will be difficult to account for water quality changes on decadal time scales, but available data will be analyzed and presented to describe historical conditions and their departure from current conditions, to the extent possible. All federal, state, and local sources of historic water quality data will be queried. Emphasis will be placed on parameters in Task 2. A preliminary screening will be made of data as to period(s) of record, spatial coverage, methodologies, and quality assurance measures. Parameters with sufficient data records will be analyzed using a variety of statistical methods to portray antecedent conditions, and these conditions will be compared to modern data. Qualitative comparisons will be made if required by data-deficiencies.

Task 4. Shellfish Sanitation Survey. This task provides for step-wise assessment of shellfish sanitation in the Bay. An initial survey will be conducted during a dry season and again during a wet season. The initial survey will be performed at 3 stations situated in each of 10 bay sub-segments defined by Estero Bay Marine Laboratory (1998). Small sub-segments may have fewer than 3 stations and larger sub-segments may have more. At each station, composite samples will be collected during a low tide for water, sediment, and tissues. Tissue samples will be collected from intertidal specimens of eastern oyster, Crassostrea virginica, wherever possible. If a sampling area lacks oysters, tissue will be sampled from the bivalve species judged to be dominant in the area. Water, sediment, and tissue samples will be analyzed for total coliform, fecal coliform, and fecal streptococci bacteria. Tissue samples will be analyzed for (1) phytoxins associated with shellfish poisoning, especially neurotoxic shellfish poison from Gymnodinium breve, (2) agents of bacterial gastroenteritis (Vibrio cholerae, V. vulnificus, V. parahemolyticus), and (3) viral pathogens (Norwalk-like viruses, poliovirus, echovirus). Depending on the severity and geographic extent of bacterial pathogens in the Bay, a follow-up study should be undertaken, employing methods of coliform DNA analysis performed in Apalachicola and Rookery Bays, and the New River (Broward County).

Quality Assurance: See Appendix 1

Data Management: See Appendix 2

References:

Estero Bay Marine Laboratory. 1998. 1997-1998 research studies, Estero Bay Aquatic Preserve, Lee County, Florida. Ostego Bay Foundation, Fort Myers Beach. var page.

Florida Department of Environmental Protection, 1996. State Water Quality Standards, S.62-302 Florida Administrative Code.

4.8.5 Ecological Studies of SAV Production and Regulation

Project Title: Ecological Studies of SAV Production and Regulation

Valued Ecosystem Component: Submerged Aquatic Vegetation

Major Goal(s): Restore the area, location, species composition, and condition of submerged aquatic vegetation (SAV-- sea grasses, rooted macrophytic algae) to pre-development conditions.

Question(s): See Background

Duration: 36-48 months

Leads From Project(s): SAV History and Trend Analysis

Leads To Project(s): Bay Water Quality Model Applications

Executable With Project(s): History and Trend Analysis of VEC Stressors

<u>Scope of Work</u>

Background: Other elements of the Estero Bay Research Plan develop data on the status and trends for SAV and SAV stressors of a physico-chemical nature. In order to identify management actions required to modify flows, salinity, nutrient loads, and other stressors for the benefit of SAV it will be necessary to understand their causal relationship. Scant data exist for seagrass condition in Estero Bay, especially regarding the covariation of condition and physico-chemical parameters. No data exist regarding the role of biotic interactions regulating seagrasses. It will be necessary to employ intensive ecological studies in sentinel seagrass beds and in experimental mesocosms to provide the required data. Such studies in Estero Bay should be coordinated closely with ongoing studies in Tarpon Bay. Task 1 employs sentinel seagrass beds to answer these EBRP questions: What are the present-day seasonal requirements and limits of SAV species diversity, shoot density, biomass, net production, etc., in statistically significant terms of water temperature, salinity, light availability, nutrients, dissolved oxygen, current speed, wave energy, sediment structure, and tidal exposure values (for SAV)? Task 2 employs mesocosm experiments to answer these EBRP questions: Is physical recruitment a significant factor limiting SAV abundance and production in the Bay? How? Do biological interactions regulate SAV more than abiotic stressors, specifically in terms of epiphytic or drift macroalgal inhibition of SAV?

Task 1. Abiotic Bay Conditions Regulating SAV. This task will evaluate the relationship of seagrass condition measures to variation in physico-chemical conditions. Up to 6 seagrass beds will be selected as "sentinel" sites for intensive study. Sites will be representative of SAV beds in Estero Bay and will include beds of only turtlegrass (Thalassia testudinum) and only shoal grass (Halodule wrightii). As local conditions allow, beds containing both species or beds of only wigeongrass (Ruppia maritima) may be occupied. Topographic features of each bed will be surveyed and thickness and composition of underlying sediments will be characterized. Each bed will be outfitted with continuous recorders of water quality measured in-situ. All instruments will be deployed off the bottom and will be submerged during low tides. Instruments will measure and record water temperature, pH, conductivity, and dissolved oxygen on 30 minute intervals. Sentinel beds also be outfitted with continuous recorders of in-situ light climate. Such instruments will have multiple sensors in order to allow for the computation of extinction coefficients. At least two full water years of data should be collected at all stations, allowing as needed for data gaps caused by servicing, replacements, calibrations, and other maintenance duties. On a twice-monthly basis, a mid-depth sample will be collected and returned from each station and visit, and analyzed for color, chlorophyll a, total suspended solids, mineral and organic turbidity, and nutrients (N and P). Nutrients will include nitrate plus nitrite, ammonia, total kjeldahl, and total nitrogen forms, plus orthophosphorus and total phosphorus. Water depth and secchi disk depth will be recorded once per station visit. Seagrass condition will be determined by destructive and non-destructive sampling. Seagrass condition will be defined in terms of percent cover, shoot density, blade density, blade width and length, epiphyte burden, above and below ground biomass, and above-ground growth rates. Above-ground measurements will be made in large quadrats and below ground samples will be taken with small cores.

Task 2. Biotic Conditions Regulating SAV. This task investigates the role of recruitment and macroalgal competition as regulators of seagrass condition. Competitive effects of epiphytic algae are addressed in Task 1. *Recruitment limitations* shall be investigated using a series of experimental transplant sites located in bay areas that are vegetated and unvegetated. One or more donor sites will be identified for shoal grass (Halodule wrightii) and turtle grass (Thalassia testudinum), and their elevations will be matched with prospective transplant sites. In collaboration with the Florida Marine Research Institute, from whom permits for seagrass transplants will be required, materials will be moved by approved methods to receiving sites. Transplants will be performed twice, prior to and at the end of the seagrass growing seasons. Sites will be monitored every-other month using non-destructive techniques (percent cover, blade density, etc.).

Inhibitory effects of drift macroalgae will be investigated by mesocosm experiments. At or near one or more sentinel seagrass bed(s), enclosures will be constructed in replicate sets, with control enclosures. Enclosures will contain pure or mixed assemblages of shoal grass (Halodule wrightii) and/or turtle grass (Thalassia testudinum). Treatments will include increasing volumes or wet-weight biomasses of drift macro-algae dominant in the Bay at the start of the seagrass growing season. Controls will contain no algae, and algae colonizing control enclosures will be removed by hand. Seasonal succession in dominant drift species will be accommodated either by replacing algae or starting new series of enclosures. Algal and seagrass parameters will be monitored twice monthly. Wet-weight biomass and/or volume of algae will be measured and algae will be returned to the enclosure. Seagrass condition will be characterized by percent cover, blade density, blade length and width, and percent senescent/chlorotic blade length. This experiment will run for at least 18 months.

Quality Assurance: See Appendix 1

Data Management: See Appendix 2

4.8.6 Ecological Studies of Shellfish Production, Regulation, and Sanitation

Project Title: Ecological Studies of Shellfish Production, Regulation, and Sanitation

Valued Ecosystem Component: Shellfish

Major Goal: Create conditions of water quality necessary to increase the area of Estero Bay designated as Class II (shellfish propagation or harvesting) waters of the State, and permit some area of the Bay to be classified "approved" for shellfish consumption.

Question(s): See Background

Duration: 24 months

Leads From Project(s): Mollusc History and Trend Analysis

Leads To Project(s): Bay Water Quality Model Applications

Executable With Project(s): History and Trend Analysis of VEC Stressors

<u>Scope of Work</u>

Background: This study addresses physical and biological factors addressing the regulation of shellfish abundance in the bay, and the factors affecting shellfish sanitation. Other elements of the Estero Bay Research Plan develop data on the status and trends for shellfish and shellfish stressors of a physico-chemical nature. In order to identify management actions required to modify flows, salinity, pathogen loads, and other stressors for the benefit of increasing safe shellfish harvest potential, it will be necessary to understand their causal relationship. Some historic data exist for oyster reef condition in Estero Bay, including data regarding the role of predators. It will be necessary to employ intensive ecological studies in sentinel oyster reefs and beds of other bivalves to provide the required data. Two tasks are defined to (1) evaluate abiotic and biotic conditions regulating shellfish, and (2) assess factors regulating shellfish sanitation. The tasks address the following questions. What are the present-day seasonal requirements and limits of shellfish diversity, abundance, in statistically significant terms of water temperature, salinity, light availability, nutrients, dissolved oxygen, current speed, wave energy, sediment structure, and tidal exposure values? Do biological interactions regulate shellfish more than abiotic stressors, specifically in terms of pathogens, parasites, or predators? What are the sources, transport mechanisms, and residence times of pathogens in the Bay? What are the rates of pathogen bioaccumulation and depuration in Bay shellfish?

Task 1. Abiotic and Biotic Conditions Regulating Shellfish. This task employs experimental installations of oyster cultch and live oysters at a number of locations throughout the Bay. Suitable donor reefs will be identified by reconnaissance. Donor reefs will have living oysters 3-10 cm in height and low incidences of parasites or disease. Individual oysters will be segregated, measured for length and weight, and tagged. Three sets of 100 identifiable oysters per set will be deployed near mean tide level at 11 stations outfitted with continuous in-situ recorders of water quality (ref. History and Trend Analysis for VEC Stressors). A Gulf station will not be occupied for oyster study. If needed, additional instrumentation will be deployed in order to occupy a station near Hendry Creek/Needmore Point reefs studied by Tabb et al. (1974). At one station only, three sets of oysters will be deployed at mean higher high water and another three sets will be deployed at mean lower low water (for a total of 9 sets at that station). Oysters will be soaked for the duration of the in-situ water quality sampling and measurement program (minimum of 12 months). Every second month, dead oysters will be counted, measured, and replaced with new tagged oysters. At the same time, height and total weight will be measured for each oyster and each will be examined for external evidence of predation, parasitism, or disease. From each set of oysters, 15 will be shucked for meat weight and fresh material will be examined for signs of protist or fungal infections. At each station, 3 trays of washed cultch will be monitored bimonthly for spat settlement. Corrections for allometric growth will be used in analyzing oyster size and weight data.

Task 2. Dynamics of Shellfish Sanitation. This task provides for process-related research on origins, fates, and effects of pathogens associated with shellfish sanitation in Estero Bay, although research designs cannot be developed until the results are known from "Molluscan History and Trend Analysis, Task 4, Shellfish Sanitation Survey." The objective of this research should be a determination of antecedent rainfall and runoff conditions beyond which Estero Bay should be closed for shellfish harvest, and a determination of depuration rates based on field studies and laboratory experiments.

Quality Assurance: See Appendix 1

Data Management: See Appendix 2

References:

Tabb, D.C., R.G. Rehrer, P. Larsen, S. Berkeley, E.J. Heald, M.A. Roessler and T.A. Alexander. 1974. Ecological inventory of coastal waters and adjacent uplands of Lee County, Florida in the vicinity of the Estero Bay Marine Preserve. UM_RSMAS Report No. 75013.

4.8.7 Sedimentology

Project Title: Sedimentology

Valued Ecosystem Component:

Major Goal(s): Restore the area, location, species composition, and condition of submerged aquatic vegetation (SAV-- sea grasses, rooted macrophytic algae) to pre-development conditions; create conditions of water quality necessary to increase the area of Estero Bay designated as Class II (shellfish propagation or harvesting) waters of the State, and permit some area of the Bay to be classified "approved" for shellfish consumption, and register the location, size, and duration of oligohaline habitat (salinity less than 10 parts per thousand) to pre-development conditions.

Question(s): What are the present-day spatial characteristics of Bay sediments with respect to age, provenance, transport, and deposition, thickness, granulometry, and mineral composition, organic content and oxygen demand; and anthropogenic contaminant concentrations? What changes in sediment characteristics have occurred in recent times?

Duration: 36 months

Leads From Project(s): No antecedent.

Leads To Project(s): Ecological Studies of Shellfish Production, Regulation and Sanitation

Executable With Project(s): Independent

Scope of Work

Background: Compared to other Florida bays, Estero Bay is a shallow, well-drained system. Tidal flats are extensive and effects of a slowing rising sea are apparent. Geological structures and processes in the bay, watershed, and inshore shelf are probably the dominant regulators of Estero Bay's hydrology, water quality, and ecology. Impacts of stressors or trends in valued ecosystem components can be understood and managed only by understanding factors which control the Bay's geomorphology. The Bay's geology is understood generally but much must be learned to place management issues of water quality and ecology in proper perspective. Details are needed of processes leading to the formation of the Bay, barrier islands and inlets, shorelines, and tributaries. How are bay sediments composed as particles and minerals; where have they originated; and are they contaminated by human action? These are among the major questions in need of study. A set of tasks is defined below, moving from structural and historical topics through sediment dynamics, and ending with studies of sediment pollution. Aspects of these tasks may be undertaken with other EBRP elements for economy, but are scoped here as separate undertakings. For example, sediment contamination work provides for a scan of pollutants in oyster tissues. Selection of oyster sampling sites must be informed by results of sediment analyses, and analysis of oyster tissue requires the same sophisticated analytical instrumentation as the sediment contaminant analyses.

Task 1. Depositional History. This task provides for geological studies encompassing Estero Bay and watershed, barrier islands, and near shore marine environments including Estero Bay and lower Caloosahatchee River. Cross-sections of the region will be constructed at high spatial density. At least three techniques will be employed: high resolution seismic profiling, vibracores, and sediment samples. Controlling structures such as karst and fracture-controlled features and pleistocene barrier platforms will be identified, chronologically sequenced, and mapped to depict the region's stratigraphy and evolution. Sampling will include cores in freshwater and marine peats, relict dunes and swales, marshes and mangrove forests, tide flats, channels, and barrier islands. Evidence (granulometry, mineralogy, radio-isotope dates, paleontology) will be sought in surficial sediment samples for carbonate/siliclastic dominance (marine and inlet-tidal deposits vs terrestrial/fluvial deposits), reworking due to recent high stands of sea level, and the effects of storms during the past 500-1000 years. Results will be correlated with and interpreted using existing geological studies of San Carlos Bay, Estero Bay, and the southwest Florida shelf. Biofacies maps will summarize surficial bottom conditions in the Bay and depict, where possible, historical evidence for seagrass beds, oyster reefs, and low salinity environments.

Task 2. Sediment Contamination. This task provides for sampling and analysis of surficial sediments in bay tributaries and Estero Bay. Samples will be taken near the end of a typical wet season, at a total of 50 stations located in tributaries, canals, along developed shorelines, and in open Bay areas. Lee County Environmental Laboratory's sediment stations will be occupied wherever possible but special effort will be made to sample sediments in north Bay areas, especially Matanzas Pass. Five stations will coincide with sampling sites occupied in the U.S. Geological Survey's study for SFWMD (Fernandez, 1998). At all 50 stations, grain size, organic carbon content and $CaCO_3$ content will be determined, as well as metal enrichment relative to aluminum concentrations. Metal enrichment will be determined for copper, lead, and zinc. From additional material collected at all 50 stations, analyses will be performed at the 25 most contaminated stations for mercury and toxic organic compounds (petroleum hydrocarbons, polynuclear aromatic hydrocarbons, chlorinated pesticides, and polychlorinated biphenyls). At or near the ten stations found to have sediments contaminated most by one or more toxic substances, tissues of intertidal oysters will be collected and analyzed for copper, lead, zinc, mercury, and toxic organic compounds. Maps will be produced depicting the granulometry, especially of silt/clay fractions, and mineralogy, including percent organic and $CaCO_3$ contents, of surficial sediments. Contaminant data will be compared to historic data and data from other estuaries.

Quality Assurance: See Appendix 1

Data Management: See Appendix 2

References:

Fernandez, M. 1998. Preliminary Reconnaissance for the Presence of Nutrients, Selected Organic Compounds and Trace Elements in Bottom Sediment in the Caloosahatchee Estuary, San Carlos Bay, Estero Bay and Pine Island Sound. USGS Coastal Marine Geology, Geologic Division Work Plan, St. Petersburg FL. 11 p.

4.8.8 Bay Water Quality Model

Project Title: Bay Water Quality Model

Valued Ecosystem Component(s): Submerged Aquatic Vegetation, Molluscan Shellfish, Oligohaline Habitat.

Major Goal(s): All

Question(s): See Background

Duration: Ongoing

Leads From Project(s): All

Leads To Project(s): Implementation of Regulatory and Planning Responses

Executable With Project(s): Independent

<u>Scope of Work</u>

Background: As part of a larger study undertaken by the University of Florida and sponsored by the South Florida Water Management District, a 3 dimensional curvilinear grid and boundary hydrodynamic and water quality model of lower Charlotte Harbor, Caloosahatchee River, and Estero Bay will be calibrated, verified, and applied to such management problems as optimal freshwater discharges, and impacts of Sanibel causeway construction. The model incorporates data on bay depths, shoreline shapes, and bottom types; uses freshwater inflow and tidal variation as forcing functions, and computes patterns of circulation, flushing, and salinity for variable periods of time. The model also computes water quality conditions in the bay, including some biological attributes. Although plans are set for data collection and model construction, aspects of the Estero Bay

Research Plan may be helpful in defining model runs, output files, and applications to management issues facing Estero Bay. Aspects are organized into four tasks and corresponding EBRP questions.

Task 1. Physical History. This "task" describes work needed to make hindcasts of physical and chemical conditions in the bay. The EBRP question, "What major physical changes have occurred in the study area, in terms of: topography of the watershed and bathymetry of the Bay, its tributaries, or Gulf connections?" leads to the recommendation that a second set of model input files be created to represent historical conditions. By this recommendation, the geometry of the Bay would be naturalized to remove filled shorelines and dredged channels. Inlets would be configured to an historic condition. Fresh water inflows would simulate runoff from undeveloped watersheds.

Task 2. Model Application. This task applies to both modern and historical (hindcast) conditions. The relevant EBRP question is, "What statistically significant relationships describe the variation of VEC stressors, as functions of the variation in values of freshwater inflow quantity, quality, and timing, for stressor values measured in freshwater inflows, and for stressor values measured in the Bay? The recommended set of model runs would have these aspects. First, a relatively long period of time would be simulated --at least a year. The year could be actual or synthetic with respect to freshwater inflows in order to capture a typical water year. Output data for salinity and other water quality parameters would be compiled so as to allow isopleth maps of the bay to be drawn. Maps will be compatible with District GIS. One series of maps will depict over-all average conditions over the simulated year(s). A second series will depict ranges of parameter values. A third series will depict some statistic of variance among data (standard deviation, coefficient of variation, etc.). The three series will be repeated for data filtered from output files to depict conditions during all high tides, and also for all low tides. All iterations will depict the behavior of the 10 part per thousand isohaline. Two GIS applications then follow. In the first, spatial analyses seek matches between mapped model outputs and resource maps developed for the Bay. Second, changes in the Bay's physico-chemical conditions (historic vs. modern) are depicted and matches are sought between these changes and changes established for resources as part of the trend analyses in the EBRP.

Task 3. Watershed Scenario Tests. What changes in the quantity, quality, or timing of freshwater inflow must be achieved to relieve stressors regulating VEC? VEC requirements will be determined through the status and trend questions and causal process questions answered by the seven EBRP investigations. These requirements will be illuminated further by spatial analyses recommended in Task 2 above. If, for example, it is determined through field studies and model hindcasting that oligohaline habitats were originally constrained to the eastern shore of the Bay, but waters of low salinity now extend farther into the Bay, for longer times, the model can be employed to determine what reductions to flow or changes in the timing of flow would restore oligohaline waters to more natural locations.

Task 4. Sea Level Scenario Tests. Sea level has been rising slowly and there is ample evidence for it in the ecology of shorelines and shallow waters around Florida. The rate of sea level rise may increase. In light of Estero Bay's very shallow nature the EBRP asked, "Is sea level rise a significant factor affecting valued ecosystem components in the Bay, in terms of regulating Bay geometry, elevation, sedimentation, or tidal exposure, altering circulation, flushing, or salinity in open waters or tributaries, or decreasing maximum depths of submerged aquatic vegetation?" A recommended use of the hydrodynamic model involves the comparison of historic or modern outputs to the results of a model run in which sea level is increased by a conservative amount. Sea level is presently rising at a rate of approximately 2.1 mm per year. At that rate, in 100 years sea level will be 21.0 cm above its present level, not counting anthropogenic acceleration.

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Quality Assurance: See Appendix 1

Data Management: See Appendix 2

Appendix I. Quality Assurance

Quality assurance entails policies and procedures ensuring that programs of sampling and measurement result in data of known precision and accuracy. QA tools include written procedures for standard procedures, lists of methods selected for use, protocols for sample custody, and provisions for QA audits, corrective actions, and reporting.

An essential element of QA is demonstrating that proposed methods will achieve targets set for two principal and two secondary objectives. Principal objectives include precision and accuracy of measurements, and these targets should be identified for each parameter prior to sampling. Methods of sampling should be appropriate to achieve the targets. Secondary objectives are completeness and representativeness. In general, a data-base containing 90-95% of data intended for collection is considered complete. Comparability is a more qualitative test that data from a new sampling program will be comparable to data from other programs.

Project sponsors often require that investigators prepare a project QA plan. Elements of an acceptable project QA plan are available from the U.S. Environmental Protection Agency and Florida Department of Environmental Protection. Florida DEP provides formats for project QA plans via its internet web-site (*http://www.dep.state.fl.us/labs/qamanual.htm*). The format required of investigators is determined by the project sponsor.

Historically, projects funded by EPA or FDEP have required the preparation of a project QA plan. Projects funded by water management districts have required an FDEP project QA plan if pass-through funds from the Surface Water Improvement and Management (SWIM) Program were used to sponsor the project. In such cases, a water management district transmits the project QA plan to FDEP for review and approval.

State review of project QA plans requires that the investigator's institution already have an FDEP-approved comprehensive QA plan. Short-form applications for Comp QAP approval are available from FDEP's web-site.

Depending on the source of funds used to underwrite a project, sponsoring agencies may elect to waive the requirement for a project QA plan. Waivers may also be granted for projects that fall under the broad classification of engineering, surveying, or physical oceanography. Sponsors may also elect to review project QA plans internally or with extramural expert assistance. Waivers are sometimes granted to projects conducted primarily by agency staff.

Most of the studies in the Estero Bay Research Plan should have a project QA plan prepared as an early project task. Formats, contents, auditing provisions, and plan approval criteria will be decided by the sponsoring agency. Requests for Proposals will state QA requirements for individual projects, and project budgets should provide funds for implementation of project QA plans.

Appendix II. Data Management

Data management entails policies and procedures ensuring that programs of sampling and measurement result in data that are stored, retrieved, and reported by approved methods. Data management tools include written descriptions of standard procedures for data screening, data entry, file structure, meta-data structure, networking, and archiving.

Project sponsors often require that investigators prepare a project data management plan. Typically, the plan must comply with data management policies and procedures employed by the project sponsor. Among federal agencies, some types of data may be managed through a common system such as STORET (for water quality data), but NOAA, EPA, and the Army Corps of Engineers manage unique data bases for other types of information. At the state level, Florida Marine Research Institute has developed protocols for data base management in geographic information system (GIS) environments. Water management districts have GIS protocols that conform with FMRI protocols to varying degrees. Districts may also have unique data management requirements. In general, then, the format required of investigators is determined by the project sponsor. Depending on the source of funds used to underwrite a project, sponsoring agencies may elect to waive the requirement for a project-specific data management plan.

Most of the studies in the Estero Bay Research Plan should have a project data management plan prepared as an early project task. Formats, contents, auditing provisions, and plan approval criteria will be decided by the sponsoring agency. Requests for Proposals will state data management requirements for individual projects, and project budgets should provide funds for implementation of project data management plans.

Estero Bay science and management will be improved through the development and adoption of a centralized geographic information system. Though unsuited for some forms of data, most of the data anticipated from the Estero Bay Research Plan could be managed through GIS. Historic, trend, and other spatial analyses, especially those based on repeated sampling and measurement efforts, mapping, and related data sources should be a central aspect of future bay science and management.

Estero Bay & Watershed Quality Assurance and Control

Control Form

QUALITY CONTROL TRACKING “STAMP”						
ACTIVITY	**PROJECT TASK AND/OR DELIVERABLE**					
READY FOR QA/QC REVIEW	**LTP:**					
	DATE					
QC REVIEWER #1 (YELLOW = OK) (RED = CORRECTION)	**QCR:**					
	DATE					
QC REVIEWER #2 (YELLOW = OK) (RED = CORRECTION)	**QCR:**					
	DATE					
CONCURRENCE (RED CHECK)	**LTP:**					
	DATE					
CHANGES MADE (YELLOW OVER RED)	**LTP:**					
	DATE					
CHANGES VERIFIED (GREEN CHECK = OK) (GREEN CIRCLE = FIX)	**QCR:**					
	DATE					
FINAL PROJECT MANAGER REVIEW	**PM:**					
	DATE					
ESTERO BAY & WATERSHED ASSESSMENT						**PBS&J July 1997**